OMB Number: 4040-0004
Expiration Date: 12/31/2019

Application for Federal Assistance SF-424

* 1. Type of Submission:
- [ ] Preapplication
- [x] Application
- [ ] Changed/Corrected Application

* 2. Type of Application:
- [x] New
- [ ] Continuation
- [ ] Revision

* If Revision, select appropriate letter(s):

* Other (Specify):

* 3. Date Received: 09/30/2019

4. Applicant Identifier:

5a. Federal Entity Identifier:

5b. Federal Award Identifier:

State Use Only:

6. Date Received by State:

7. State Application Identifier:

8. APPLICANT INFORMATION:

* a. Legal Name: Duke University

* b. Employer/Taxpayer Identification Number (EIN/TIN): 56-0532129

* c. Organizational DUNS: 0443877930000

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County/Parish: Durham
* State: NC: North Carolina
Province:
* Country: USA: UNITED STATES
* Zip / Postal Code: 27705-4677

e. Organizational Unit:

Department Name: Civil and Env. Engineering

Division Name: Pratt School of Engineering

f. Name and contact information of person to be contacted on matters involving this application:

Prefix:
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Middle Name: E.
* Last Name: Borsuk
Suffix:

Title: Associate Professor

Organizational Affiliation: Civil and Environmental Engineering

* Telephone Number: 919-660-1767
Fax Number:

* Email: mark.borsuk@duke.edu

Application for Federal Assistance SF-424

*** 9. Type of Applicant 1: Select Applicant Type:**

O: Private Institution of Higher Education

Type of Applicant 2: Select Applicant Type:

Type of Applicant 3: Select Applicant Type:

* Other (specify):

*** 10. Name of Federal Agency:**

Environmental Protection Agency

11. Catalog of Federal Domestic Assistance Number:

66.509

CFDA Title:

Science To Achieve Results (STAR) Research Program

*** 12. Funding Opportunity Number:**

EPA-G2019-STAR-E1

* Title:

Contaminated Sites, Natural Disasters, Changing Environmental Conditions and Vulnerable Communities: Research to Build Resilience

13. Competition Identification Number:

Title:

14. Areas Affected by Project (Cities, Counties, States, etc.):

Add Attachment | Delete Attachment | View Attachment

*** 15. Descriptive Title of Applicant's Project:**

Building community resilience to natural-disaster-driven contaminant exposures through system-level risk analysis, management, and readiness

Attach supporting documents as specified in agency instructions.

Add Attachments | Delete Attachments | View Attachments

Application for Federal Assistance SF-424

16. Congressional Districts Of:

* a. Applicant: NC-001 * b. Program/Project: NC-001

Attach an additional list of Program/Project Congressional Districts if needed.

Add Attachment | Delete Attachment | View Attachment

17. Proposed Project:

* a. Start Date: 05/01/2020 * b. End Date: 04/30/2023

18. Estimated Funding ($):

* a. Federal	799,756.00
* b. Applicant	0.00
* c. State	0.00
* d. Local	0.00
* e. Other	0.00
* f. Program Income	0.00
* g. TOTAL	799,756.00

*** 19. Is Application Subject to Review By State Under Executive Order 12372 Process?**

☐ a. This application was made available to the State under the Executive Order 12372 Process for review on .

☐ b. Program is subject to E.O. 12372 but has not been selected by the State for review.

☒ c. Program is not covered by E.O. 12372.

*** 20. Is the Applicant Delinquent On Any Federal Debt? (If "Yes," provide explanation in attachment.)**

☐ Yes ☒ No

If "Yes", provide explanation and attach

Add Attachment | Delete Attachment | View Attachment

21. *By signing this application, I certify (1) to the statements contained in the list of certifications and (2) that the statements herein are true, complete and accurate to the best of my knowledge. I also provide the required assurances** and agree to comply with any resulting terms if I accept an award. I am aware that any false, fictitious, or fraudulent statements or claims may subject me to criminal, civil, or administrative penalties. (U.S. Code, Title 218, Section 1001)**

☒ ** I AGREE

** The list of certifications and assurances, or an internet site where you may obtain this list, is contained in the announcement or agency specific instructions.

Authorized Representative:

Prefix: * First Name: Lauren

Middle Name:

* Last Name: Faber

Suffix:

* Title: Assistant Director, ORS

* Telephone Number: 919-684-3030 Fax Number: 919-684-2418

* Email: ors-grant@duke.edu

* Signature of Authorized Representative: Susan Lasley * Date Signed: 09/30/2019

OMB Number: 2030-0020
Expiration Date: 04/30/2021

EPA KEY CONTACTS FORM

Authorized Representative: *Original awards and amendments will be sent to this individual for review and acceptance, unless otherwise indicated.*

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City: Durham **State:** NC: North Carolina

Zip / Postal Code: 27705-4677 **Country:** USA: UNITED STATES

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EPA KEY CONTACTS FORM

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Last Name: Borsuk | **Suffix:**

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CONTENTS

ABSTRACT

a. **Funding Opportunity:** Contaminated Sites, Natural Hazards, Changing Environmental Conditions, Vulnerable Communities: Research to Build Resilience: EPA-G2019-STAR-E1
b. **Title:** Building community resilience to natural-disaster-driven contaminant exposures through system-level risk analysis, management, and readiness
c. **Investigators:** Mark Borsuk (Contact PI); Sacoby Wilson (PI); Marccus Hendricks (Co-I)
Email Contact: mark.borsuk@duke.edu
d. **Institutions:** Duke University, Durham, NC; University of Maryland, College Park, MD
e. **Project Period and Location:** 5/1/20-4/30/23; Durham, NC; College Park, MD
f. **Project Cost:** $799,756
g. **Project Summary:** ***Objectives.*** The overarching goal of the proposed project is to assist communities in developing comprehensive strategies for building resilience to contaminant releases associated with natural hazards. We propose to accomplish this via the following objectives:
    1. Develop a generalizable and comprehensive risk analysis framework that links natural hazards and changing environmental conditions to the release, fate, and transport of contaminants.
    2. Collaborate with community partners to identify factors that may modify exposure and vulnerability of certain populations and include such factors in our framework to holistically assess health risks.
    3. Assist communities in translating scientific products into realistic and relevant management and readiness plans that promote community resilience to natural hazards.

Approach: We will develop a systems model in the form of a Bayesian Network that articulates interacting meteorological, contaminant release and transport, human exposure, and epidemiological processes within a unified probabilistic framework. This approach will provide urgently needed capacity to characterize risks that result from as-yet poorly defined interactions across natural, technological, and socio-economic systems. We will leverage the deep expertise of our interdisciplinary team in environmental engineering, public and environmental health, planning, environmental justice, and community engagement, with our experience structuring complex socio-environmental processes into quantitative risk analysis frameworks. Crucially, knowledge generated by this project will be co-produced with long-standing partners from two specific communities at risk of natural-disaster-driven contaminant exposures. This close collaboration will enable translation of models and results into improved community readiness and resilience.

Expected Results. Planned ***outputs*** of this project include: a generalizable, modular tool to evaluate risks of contaminant exposures to vulnerable communities under diverse natural hazard conditions and scenarios; specific model-based analyses and field study of one urban and one rural community, with a focus on young children and the elderly; strategies for risk mitigation, such as awareness campaigns, health promotion, and emergency readiness plans, co-developed with community stakeholders. Project ***outcomes*** include: a generalizable framework for quantification of the additional risks borne by vulnerable populations including low-income families, children, and the elderly resulting from poorly understood vulnerabilities; enhanced readiness of communities to natural-disaster-driven contaminant exposures; and better quality and length of life in vulnerable urban and rural populations.

h. **Supplemental Keywords:** community-engaged research; total environment; sustainable and healthy communities

RESEARCH PLAN

OBJECTIVES. Environmental management and planning procedures have traditionally treated "natural" and "technological" hazards as independent phenomena. However, the recent spate of so-called "NaTech" disasters has revealed that in reality there are strong interactions between the two that appear to be intensifying. For example, changing environmental conditions have the potential to increase the risk of industrial accidents, shift the dominant contaminant transport and exposure mechanisms, and modify the capacity of affected communities to respond to crisis (1). At the same time, increasingly complex and interconnected production and supply networks may enhance the exposure of raw materials and waste products to extreme weather conditions, introduce novel and unfamiliar chemicals into the environment, and complicate source tracking and attribution of responsibility. Current chemical containment and risk mitigation plans are therefore based on increasingly outdated assessments of overall risk to surrounding communities (2, 3). **The first objective of the proposed project is to develop a generalizable and comprehensive risk analysis framework that links natural hazards and changing environmental conditions to the release, fate, and transport of contaminants.**

It is well established that in the US low-income populations and people of color are disproportionately burdened by environmental hazards such as landfills, chemical plants, incinerators, power plants, Superfund sites, and Toxics Release Inventory (TRI) events (4, 5). These groups (especially children and the elderly among them) also often face inadequate access to healthcare, reduced mobility, nutritional deficiencies, and psychosocial stressors, enhancing their vulnerability to natural and technological disasters (6-9). However, the role of each of these factors in modifying overall risks posed by NaTech events is not well understood, complicating attempts to enhance community resilience (10-12). Characterizing these vulnerabilities and identifying the best opportunities for mitigation or adaptation require a fundamentally transdisciplinary approach. **Our second objective is to work with community partners to demonstrate how factors that modify the exposure and vulnerability of certain populations to NaTech events can be identified and included in a risk analysis framework to holistically assess health risks.**

Exposure to chemical and biological contaminants associated with NaTech events is highly dependent on public response to emergency advice, such as adherence to evacuation orders (2, 9). This response in turn depends on factors such as perception of risk, mobility, social and financial assets, and trust in authorities (9, 13). Therefore, emergency response plans are more likely to produce realistic and effective procedures when the impacted communities have participated in their development (14, 15). Co-production of the research supporting such plans also serves to align incentives between scientists and communities thereby enhancing local ownership and the utility of research findings (16). **Our third objective is to assist community partners in the use of our scientific products to develop realistic and relevant management and readiness plans that promote community resilience.**

RATIONALE. NaTech events can be defined as "the significant impacts or consequences that natural hazards impose on critical or civil infrastructure and industrial facilities which result in the release of hazardous materials into the environment and impact on surrounding ecosystems, economies, and the built environment" (17). Because of the combination of technological, environmental, and social factors involved, NaTech events are especially problematic, increasing the complexity of disaster prevention, mitigation, and response efforts (18, 19). For example,

Gheorghiu et al. (20) found that accounting for NaTech scenarios when evaluating disaster risk can increase estimated probabilities of contaminant release by an order of magnitude.

There exist many publicly available tools for screening chemicals for potential health risks (21-23) and geographic areas for potential environmental hazards (24-28). Similarly, there is ample existing modeling capacity to describe environmental fate and transport of chemical contaminants under a range of transport pathways and release scenarios (29). However, these tools do not reflect the extreme conditions, initiation sequences, or transport pathways of NaTech events and are not well integrated (30, 31). For example, secondary containment structures are a common strategy to prevent off-site migration of chemicals released accidentally (32). However, hurricanes produce catastrophic winds and floods, triggering chemical releases while overwhelming the storage capacity of containment structures. This introduces transport pathways, such as overland flow, not applicable in normal circumstances (33, 34). These releases and transport pathways can lead to unexpected environmental reservoirs of contaminants, even upgradient from sources, which may persist long after the natural hazard has subsided (35). These reservoirs, including soil and water, may pose unrecognized risk to children who play outdoors. In general, there is relatively little understanding of overall risk resulting from exposure to contaminants released by natural hazards (36).

Characterizing potential human exposures from NaTech events therefore requires a reconceptualization of modeling frameworks. **Our first objective uses Bayesian networks to model the release, fate, and transport of contaminants as the product of extreme events and probabilistic processes that impact contaminant release and transport.** In a variety of previous projects, we have demonstrated the utility of nesting quantitative mechanistic and statistical models within Bayesian network "emulators" to both holistically capture model relations as well as accurately track correlated uncertainties among the component models (37-42). We have shown that, when ignored, underlying associations among model components can create erroneous assessments of risk (37). Additionally, we expect that by holistically modeling the multiple defining processes of NaTech events, we will reveal a number of transport mechanisms, exposure pathways, and vulnerability factors that are currently overlooked or misestimated by existing risk screening tools.

Individual susceptibility to risks from contaminant exposure is driven by diverse, correlated factors (43, 44). Notably, the same communities that have increased risk of *exposures* are also home to disproportionately many individuals who have increased *sensitivity* to any given exposure. For instance, race/ethnicity correlates with both increased exposure to chemical contaminants (4, 5) and food insecurity (6). Nutritional deficiencies associated with food insecurity can have dramatic impacts on the effective toxicity of contaminants. These communities also face material (e.g., lack of money) and psychosocial (e.g., lack of trust in emergency authorities) barriers to exposure reduction measures such as evacuation. The interactions between exposure, sensitivity and response variables are at present poorly understood, which has created substantial uncertainty around the most impactful strategies for risk reduction in vulnerable communities (8). **Our second objective elucidates these interactions by linking environmental contaminant exposures with the constellation of contributing factors and effect modifiers that ultimately control health outcomes**.

By explicitly characterizing the relationship between exposure and health risk, we address a shortcoming of existing modeling and screening tools and improve capacity to estimate candidate interventions in terms of their impact on endpoints of interest. Crucially, this framework can be used to reveal the differential risks faced by different demographic and

socioeconomic groups. For example, children generally have both heightened chemical exposures (e.g., more soil contact) and greater susceptibility (e.g., lower body mass, critical developmental processes) while the elderly have drastically reduced ability to evacuate as well as co-morbid health conditions (45-47).

Holistic identification, understanding, and consideration of these challenges can only come from close engagement with community partners. It is increasingly evident that emergency readiness and response plans that are co-produced with impacted communities increase both the plausibility of these plans (compatibility with social and other constraints) and the likelihood that they will be followed (48-50). Many authors and organizations have developed tools to increase trust between vulnerable communities and disaster readiness and response authorities and researchers (51-53). However, there is a lack of capacity for engaging vulnerable populations in anticipating and responding to the interacting chemical and physical risks that may pose unique dilemmas and tradeoffs (8). **Our third objective therefore seeks to promote community resilience by engaging the public and representatives of community organizations in the model-based development of emergency readiness and response plans.**

Our engagement process in collaborative scenario modeling will specifically focus on building social capital and collective efficacy in the community, and will work to enhance those capacities through education, awareness, and ultimately feedback loops that support disaster readiness and resilience planning. Assessing and improving resiliency in physically vulnerable areas and among the most socially vulnerable populations is most effective when participation from local community members is incorporated. Developing protocols that allow community members to have control and advocate for change they desire, while themselves learning adaptation techniques and risk potential of natural hazards is vital to addressing disaster readiness and resilience issues. This is especially crucial for communities impacted by the cumulative impacts of environmental hazards, in addition to other factors such as social stress and poor infrastructure.

APPROACH. **Figure 1** introduces our project structure. **Objective 1** starts by developing an improved representation of NaTech events and potential contaminant releases by translating and extending the QRA approach of Cozzani et al. (54) into a Bayesian network. This will then be linked with site and contaminant screening tools such as EJScreen and Caltox on one end, and transport models such as SWMM and SWAT on the other. Our preliminary model structure and assumptions will then be groundtruthed with community partners using community-engaged mapping, community walks, and block assessments to identify any missed sources or transport mechanisms. The output of this first phase of work will be a model-based assessment of potential NaTech-driven environmental contaminant distributions. These results will be presented to community members in the form of maps of sources and potential exposure pathways and hotspots.

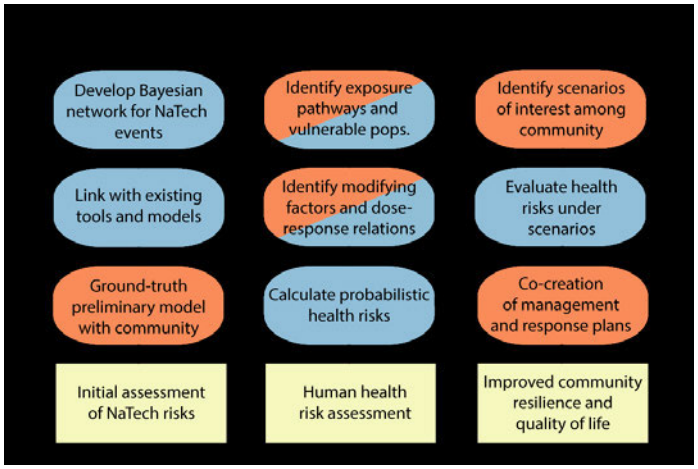

Figure 1: Project schematic. Blue ovals represent modeling tasks; orange ovals represent community engagement activities; yellow squares represent outputs and outcomes.

Objective 2, links contaminant concentrations in the environment to health risks via exposure, toxicological, and susceptibility factors. Importantly, we will work with our partner communities to identify how each community's readiness, response, and recovery in the case of a NaTech event will determine residents' contaminant exposure, with particular attention paid to the poor, the very young, and the elderly. We will also seek to mutually identify the economic, social, cultural, institutional, political and psychological factors that would exacerbate vulnerability by affecting factors such as evacuation capability, access to emergency or long-term healthcare, and nutritional status. These factors will be included in our Bayesian network model with particular attention to interactions among risk factors that are not well addressed by other modeling tools. The output will be an advanced health risk screening and assessment tool for NaTech events that accounts for community and individual level contributing factors.

Finally, in **Objective 3**, we will work with community partners to identify and model specific risk conditions and disaster scenarios of critical importance to groups with underlying social, economic, geographic, or health vulnerabilities; susceptible populations (children and the elderly); and/or high local interest (i.e., local areas that consistently flood near industrial operations). The results will be used in collaboration with communities to create maps and toolkits that will assist in the development of NaTech disaster readiness and response plans.

STUDY AREAS. We will pursue our project objectives in the context of two communities that are especially susceptible to contaminant exposures resulting from, or exacerbated by, extreme events likely to worsen as a result of future environmental change, including flash floods, storm surges, and hurricanes. Our choice of communities will allow us to compare relevant factors across urban and rural communities, and extend the generalizability of our tools and results.

North Charleston, South Carolina. Like most urban areas, North Charleston (**Figure 2**) is home to extensive industrial assets, such as chemical plants and wholesalers, manufacturing facilities, petroleum bulk storage terminals, power plants, a paper mill, nonmetallic mineral production sites, metal processing facilities, hazardous waste recycling facilities, and major wastewater and drinking water treatment plants (55, 56). Additionally, the Port of Charleston, with its three terminals on the Charleston peninsula and another on the Wando River, is the fourth largest in the country and the busiest in the southeastern United States (57). It is also part of a larger distribution network comprised of railways, highways, and shipways. Many of these sites contain above- or underground storage tanks. Extreme hydrological events can cause chemical releases from tank flotation, rupture, overfill, or spills, which can migrate offsite, posing threats to surrounding communities (58-60). Additionally, industrial emissions and the movement of goods in the region result in the deposition of a variety of heavy metals and polycyclic aromatic hydrocarbons (PAH) that may be mobilized by extreme hydrometeorological events (61, 62).

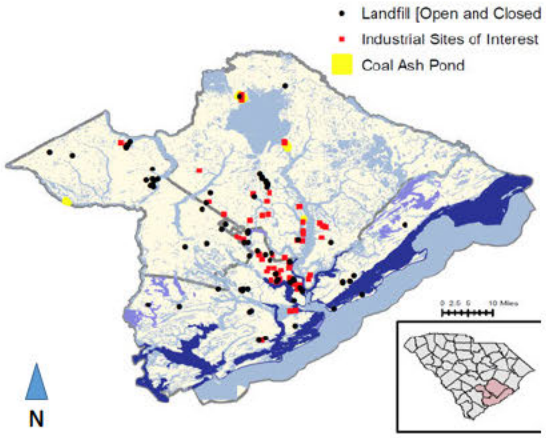

Figure 2: Map of Metropolitan Charleston, SC.

Community Partners. Members of our team have already established close links with community partners in the scope of two past NIH grants (3R21ES017950-01S1 and 1R21ES017950-01) to

study environmental justice concerns regarding industrial facilities (63-65). The ***Low Country Alliance for Model Communities (LAMC)*** represents seven economically distressed neighborhoods in North Charleston, including Union Heights, Howard Heights, Accabee, Chicora-Cherokee, Windsor, and Liberty Hill. LAMC's non-partisan, non-denominational membership has been actively engaged in developing grassroots solutions to environmental justice issues in North Charleston. ***Charleston Community Research to Action Board (CCRAB)*** is a community-based organization dedicated to promoting environmental health and social justice solutions within the Charleston region particularly for burdened and underserved communities through the translation of research to action. CCRAB is comprised of community leaders from economically distressed and overburdened neighborhoods in Charleston including Union Heights, Accabee, Chicora-Cherokee, and Rosemont.

Duplin County, North Carolina. Duplin County in eastern North Carolina (**Figure** 3) leads the US in hog production and is home to a major poultry industry (66, 67). Hog waste is managed in lagoons to promote anaerobic decomposition and liquefaction. These lagoons present a public health threat as waste with high concentrations of microbial pathogens, antibiotics, hormone residues, heavy metals and nutrients can seep into groundwater and be mobilized by extreme weather (68-70). For example, Hurricane Floyd resulted in the release of at least 7 million gallons of hog waste, exposing nearby communities to pathogenic, chemical, and other risks (71). Duplin County is also located downstream from multiple coal ash ponds associated with the H.F. Lee Energy Complex, a retired coal-fired power station in Wayne County, NC (72, 73). Coal ash ponds are filled with combustion residuals with high levels of heavy metals, notably cadmium, hexavalent chromium, lead, mercury, and selenium (74). These facilities are highly vulnerable to disturbance. For example, in 2014, a stormwater drainpipe failure resulted in the release of 39,000 tons of coal ash and 27 million gallons of ash wastewater into the Dan River, North Carolina, in what was at the time the third biggest coal ash release in US history (75). Our studies of Duplin County in this project will focus on metals, nutrients, and pathogens. We have identified likely sources and contaminants of concern through previous scoping activities, but these are subject to evaluation with community partners as described in below.

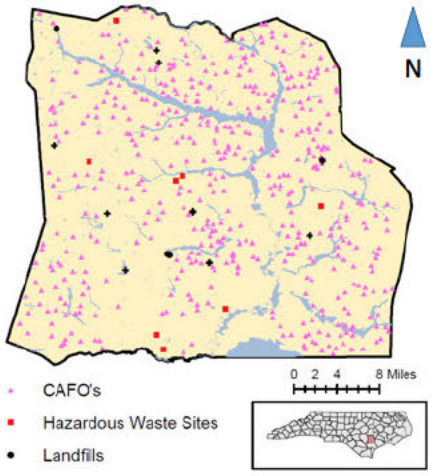

Figure 3: Map of Duplin County, NC.

Community Partners. Members of our team also have long-standing collaborations with two organizations working in Duplin County. The ***North Carolina Environmental Justice Network (NCEJN)*** is a grassroots, people of color-led coalition of community-based organizations and their supporters who work with low income communities and people of color on issues of climate, environmental, racial, and social injustice. Dr. Wilson (Co-PI) has been a member of the NCEJN and has presented research findings and provided trainings and workshops on a number of environmental justice and health topics including industrial hog farming, air pollution monitoring, CBPR, citizen science, and water quality research at the Network's Annual Community-Based EJ Summit frequently since 2002, receiving the NCEJN's Steve Wing International Environmental Justice Award in 2008. Dr. Wilson has also provided technical assistance to ***Rural Empowerment Association for Community Help (REACH)*** as a consultant

on an EPA-funded Collaborative Problem-Solving project. REACH was founded in the aftermath of Hurricane Floyd to support low-income families and people of color in eastern North Carolina. The organization has sought to address potential health effects of living close to industrial hog farms, problems stemming from mental and emotional oppression, economic inadequacies, employment and education needs, lack of single-family housing, racial and cultural imbalances, and limited youth programs and services.

While our project focuses on flooding and flood-induced contaminant transport events in two Southeastern communities, our approach and results will be generalizable to a range of natural and technological hazards occurring in other parts of the United States.

METHODS. Objective 1: Develop a risk analysis framework to link natural hazards to the release and transport of contaminants.

Bayesian Networks. Being the co-occurrence of a set of inherently stochastic events, NaTech-driven contaminant migration can be conceptualized as the joint probability distribution of natural hazards, technological failures, contaminant source vulnerability, and dominant transport mechanisms (76). As such, we plan to use a Bayesian network (BN) as our organizing risk assessment framework. A Bayesian network is a directed acyclic graph (DAG) in which variables are represented as nodes and probabilistic dependence between variables is represented by arrows. The absence of a directly connecting arrow between any two nodes implies that the two variables are conditionally independent, given the values of any intermediate nodes. This means that the probability distribution of any variable X_i in any state of the network can be determined by knowing only the values of its immediate predecessors (called its parents, PA_i), without regard to the values of any other variables. In this way, the joint probability distribution for the entire network can be written as the product of a limited number of conditional distributions using the chain rule of probability calculus:

$$P(x_1, \ldots, x_n) = \prod_{i=1}^{n} P(x_i|pa_i) \qquad [1]$$

Figure 4 illustrates a highly simplified BN representing relations among some of the key factors in a NaTech health risk assessment. Such a graphical network can usually be drawn based on mechanistic or empirical knowledge of the system. For example, the arrow from Natural Events (N) to Contaminant Transport (T) captures our assertion that the dominant mode of contaminant transport (e.g., overland vs. instream flow) will depend on the type and magnitude of the natural event. On the other hand, the absence of a direct arrow from Technological Events (E) to T indicates that, in this example, the nature of the technological event does not affect contaminant transport except via its effect on Containment Failure (F) and Materials Release (M). In probabilistic terms, F and M render T and E independent. Together with the remainder of the relationships expressed in **Figure 4**, this implies that the joint distribution of these six variables can be written in the mathematical form of eq. [1] as:

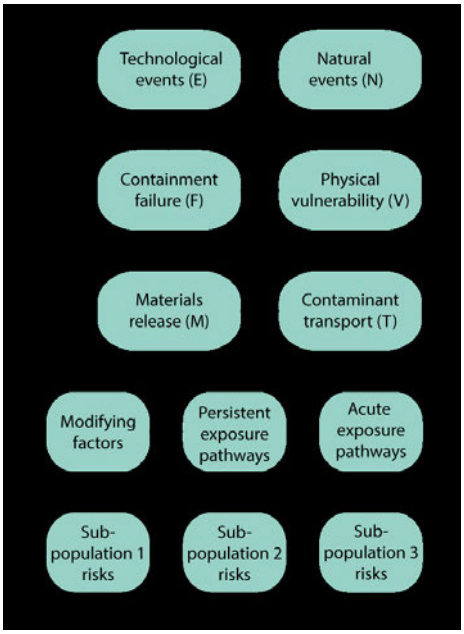

Figure 4: Simplified Bayesian network representing relations among some key factors in NaTech health risk assessment. Objective 1 focuses on the relations in the top half of the figure, while Objective 2 focuses on those in the bottom half.

$$P(T,M,N,F,E,V) = P(T|M,N) \cdot P(M|F) \cdot P(F|N,E,V) \cdot P(E|N) \cdot P(N) \cdot P(V) \quad [2]$$

The recognition that dependence relations expressed in graphical form have practical implications for determining the probabilistic relationship among variables significantly facilitates the performance of risk assessment for complex systems. For example, generating a prediction for the probability of offsite contaminant transport (T) given a particular natural event (N) can proceed by decomposing the full causal chain connecting these two variables into the conditional relationships contained in eq. [2]. These local relationships can be characterized separately using the models or data that are directly relevant and then reassembled in a way that is specified by the graph. The intuitive graphical representation of dependences in a BN also make them a useful device for communication and translation of ideas across scientific disciplines as well as between expert and lay participants in the process of model building. For these reasons, BNs have emerged as a promising alternative to conventional methods, such as reliability block diagrams, fault trees, event trees, and bow-tie diagrams, for assessing risk in a diversity of fields (77).

NaTech Modeling. Our approach in Objective 1 to modeling NaTech events using BNs will start with the Quantitative Risk Assessment (QRA) framework of Cozzani*, et al.* (60), but will be extended to take advantage of the ability of BNs to represent phenomena such as common cause failures, multilevel cascading or escalating events, nonlinear interactions, and multistate and continuous variables. Briefly, the QRA approach as described by Cozzani*, et al.* (60) proceeds as follows:

- Natural or technological "primary" events are identified (e.g., lightning strikes, flash floods, human error) that could serve as triggers for "secondary" events (e.g., power outages, containment failure).
- Natural events are assigned intensity vectors and technological events are assigned escalation vectors that characterize the magnitude of their potential effects on "secondary targets" (e.g., equipment, storage tanks).
- Secondary targets are assessed based on their physical vulnerability using probit-like damage models to relate a "dose" of physical effects (described by the intensity and escalation vectors) to the potential for structural damage and materials release.
- The potential for events to propagate is next identified through vulnerability modelling of additional secondary targets.
- Finally, for combinations of primary and secondary events, risks to workers and nearby population are assessed, accounting for their spatial location, intensity of effects, time of exposure, and possible protection offered by buildings or personal protection devices.

QRA is used widely as a tool for analyzing acute event risk of storage tank failure at industrial facilities (78, 79), including failures triggered by earthquakes and floods (80, 81). However, we plan to extend the approach's applicability to persistent exposures and to additional secondary targets including hog waste lagoons, coal ash ponds, wastewater treatment plants, and chemical stockpiles in addition to storage tanks. Accomplishing this will require the development of escalation and vulnerability representations specific to these targets. Further, QRA has not, to our knowledge, been used in association with offsite transport and exposure models to evaluate risks to neighboring communities based on local environmental conditions and vulnerability factors. Addressing these considerations is essential to obtaining a more holistic evaluation of risk. Finally, we believe that by exploiting the unique capabilities of BNs we can improve the

representation of interactions among factors and the correlation among uncertainties thereby improving the reliability of assessments.

Model Specification. Our approach to specifying our BN's component models will be to take advantage of existing screening tools and models whenever possible (**Figure 5**). For example, to identify sites and contaminants of concern we will use EJScreen (24), CalTox (21), and RSEI (26). Potential contaminant releases will then modeled as in the QRA approach described above using statistical or semi-mechanistic probabilistic functions informed by available meteorological and industrial data. For example, chemical releases listed in the Toxic Release Inventory can be cross-referenced with data on hurricane intensity, floodwater elevations and other indicators of extreme events. To the extent permitted by available data, we will develop novel models for relevant classes of contaminants and industrial sites. These will complement empirical relationships with mechanistic reasoning of failure pathways. For example, reported volumes of chemicals in use can be used to estimate the size of containment structures and hence the meteorological conditions required for chemical release. Cozzani*, et al.* (60) tabulate diverse industrial failures and release mechanisms in terms of probabilistically distributed natural events and will be a starting point for this work. To the extent possible, we will develop relationships as functions of nationally available data to maximize potential for scaling our case studies to a broadly applicable tool.

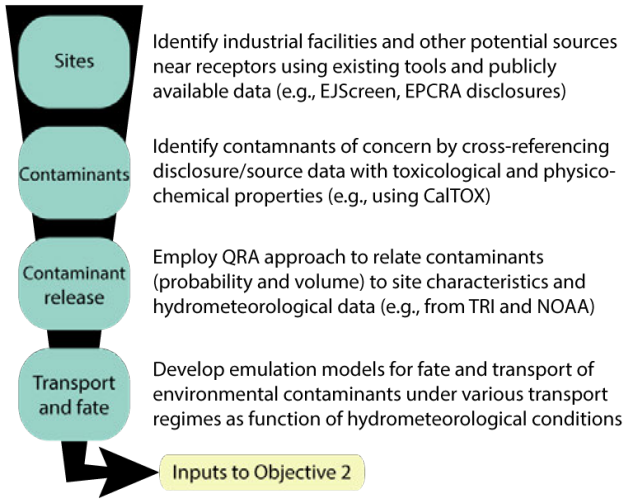

Figure 5: Workflow and expected resources for Obj. 1.

To evaluate how released hazardous materials are likely to move through the environment under alternative transport regimes we will draw on the numerous existing models. For example, the US EPA's Agricultural Runoff Management (ARM) model or Storm Water Management Model (SWMM) can be used to estimate post-event environmental distributions of contaminant hazards resulting from overland flow (82, 83) and Hydrus 1D and 2D variants provide platforms for modeling transport via groundwater (84). In previous work, we have nested such mechanistic, process-based models within probabilistic, BN frameworks using model emulation approaches (38, 85, 86). By representing models with relatively simple mathematical expressions, emulation allows multiple alternative processes within a BN, selected based on threshold criteria (e.g., precipitation intensity). Thus, the simultaneous dependence of multiple NaTech stages (e.g., contaminant release, dominant transport mechanism, exposure pathways) on characteristics of the initiating event can be represented. These highly correlated, nonlinear processes imply an irregular distribution of potential outcomes, requiring advanced probabilistic calculations that are facilitated by the BN framework.

Community Groundtruthing. To groundtruth local contaminant sources and exposure pathways and provide residents with skills as community scientists that can be used in subsequent project activities, our team will engage in mapping and community walks with

residents. The process will begin with discussion of what we have identified as pathways to hazardous material exposure and the risks associated with them. Participants will be asked to describe areas they know are problematic and engage in discussion about reliability and validity of data collection. We will then proceed with the mapping exercise and a series of community walks. We will conduct this process in both North Charleston and Duplin County.

Community-engaged mapping is a group mapping exercise designed to answer specific research questions and gather feedback from community members who live, work, or attend school in the area. It can be described as a focus group around a map because residents dialogue over maps of a neighborhood about their experience with the local physical environment. In each study community, we will have small, breakout groups that allow residents to collectively discuss and map their communities. This and other types of public participatory mapping approaches have been effectively used in previous work of the team (27, 28).

A community walk is a method in which community members walk through a neighborhood of interest to map out and collect information about their neighborhood's sites and social, economic, and cultural dynamics. It provides a first-hand view of the community, its people, and its assets and can naturally provide information needed to identify potential contaminant sources and exposure pathways. We will combine the walk with interviews of community members along the walk to find out more about specific locations. We will also take pictures of locations, to be placed on the maps produced.

Objective 2: Partner with communities to assess and model NaTech vulnerability factors. Objective 2 aims to describe changes in health risks in terms of (1) environmental distributions of contaminants estimated in Objective 1; (2) exposure pathways and toxicological processes unique to NaTech events; and (3) vulnerability factors specific to certain demographic groups, with the latter two considerations elucidated as part of this objective (**Figure 6**).

We will develop probabilistic expressions for human exposures by linking distributions of contaminants (from Objective 1) to EPA's Exposure Factors Handbook (87). The Handbook adds a further probabilistic dimension by providing, for each demographic group, percentiles for each exposure route and parameters relevant to calculating body burden (e.g., body mass). We will allow for the "default" values from the Handbook to vary according to scenarios for evacuation time and other variables developed in collaboration with local stakeholders. Dominant transport pathways calculated in Objective 1 will furthermore be linked to the calculation of exposures in Objective 2; for example, soil ingestion and surface-water exposure pathways will be relevant for simulations that imply mobilization of contaminants via overland flow, whereas consumption of well water may dominate exposures when groundwater contamination is the dominant transport pathway.

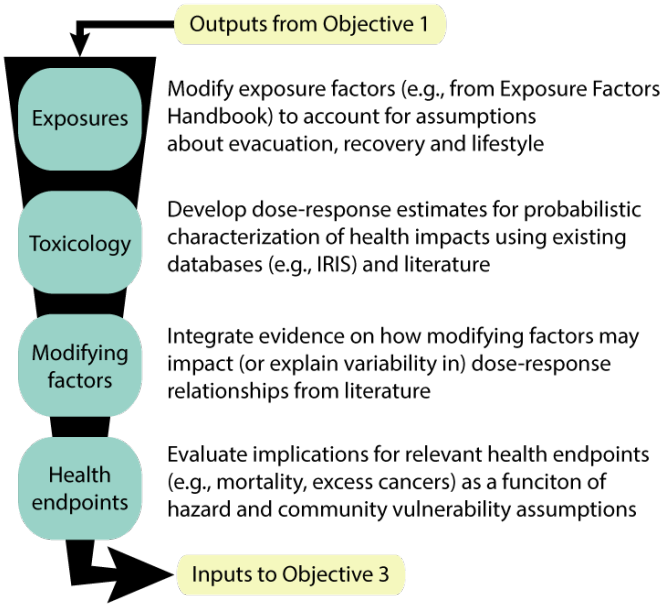

Figure 6: Workflow and expected resources for Obj. 2.

There exist many databases of confounder-adjusted dose-response relationships such as EPA's Integrated Risk Information System (IRIS) (88) and the Global Burden of Disease Study (89). In previous work, we have outlined methods for pooling epidemiological evidence on the relationship between chemical and nutrient intake and disparate outcomes (e.g., ischemic heart disease, sudden cardiac death) in terms of more general endpoints (e.g., total cardiovascular mortality) (90). We will extend these methods order to allow evaluation of the relative impact of hypothetical interventions that variously change probabilities or scenarios for contaminant release, exposure pathways and characteristics relating to vulnerability and susceptibility. We will use this framework to guide development of readiness and response tools with communities in Objective 3.

To determine factors driving vulnerability to NaTech events and resulting exposure pathways, we will employ four complementary techniques: (1) Interviews, (2) Surveys, (3) Photovoice, and (4) Block Assessment.

Interviews. We will start by conducting semi-structured, open-ended interviews with approximately 20-25 incentivized stakeholders in each study community (40-50 total, stratified to oversample the elderly and caregivers of the elderly and very young). Stakeholders will include residents, community leaders, government officials, planners, community groups, and individual residents. The interviews will be developed with questions to assess: 1) barriers to household and municipal disaster readiness; 2) identification of the most appropriate disaster preparedness approaches; and 3) individual conditions that may influence susceptibility. Significant factors will be extracted and interpreted qualitatively to determine the dominant discourses concerning disaster readiness an vulnerability in each study area. Principal Component Analysis (PCA) will be used to determine the extent to which particular individuals agree or disagree with particular factors. This will show points of agreement and divergence across a broad range of actors in the study communities.

Survey. Interviews will subsequently inform a stratified randomized survey of residents in each study community. Surveys will follow the KAP model to collect quantitative data on: 1) the relationships between demographics, knowledge, attitudes and practice towards disaster readiness and 2) social barriers, environmental justice issues, economic conditions, and other vulnerability factors that may impact disaster readiness. Online deployment will be conducted using the Qualtrics survey management service (https://www.qualtrics.com/online-sample/). Door-to-door deployment intended to reach the elderly will be conducted in partnership with LAMC, CCRAB, REACH, and the NC EJ Network consistent with the principles of CBPR. Approximately half of the respondents (stratified by sample time and neighborhood) will be targeted for participating in collaborative modeling of scenarios and toolkit development under Objective 3.

Photovoice. To give voice to youth perspectives on environmental hazards, disasters, community vulnerability, and community resiliency, and to compare youth perspectives with those of adults, we will use the innovative approach of Photovoice (91, 92) following similar approaches to those of prior projects by members of our team (93-95). Youth and adult cohorts of 15 participants will participate in two Photovoice sessions in each study community. The first session will be used to provide an overview of the project, information about the use of Photovoice in eliciting community perspectives, and details about their individual participation, consent and ethical

issues. The second session will be designed for discussion of photos—each participant will be asked to select 10 photos that they took that relate best to the assignment or were most significant to them. Then, in-depth group discussions on the photographs will be facilitated by six guiding questions following the SHOWeD method (91, 96-98). After each of the Photovoice sessions, digital audio recordings will be transcribed verbatim by project staff and/or a local transcription service. Following transcription, the project team will review the transcripts and photos to identify dominant themes, and data will then be coded within and across the different sessions into distinct categories for further analysis.

Block Assessment. Our block assessment tool is an adaptation of the multi-item Neighborhood Inventory for Environmental typology (NIfETy) (99) The items on the assessment are operationalized in six domains including: (1) physical layout, (2) types of structures, (3) adult activity, (4) youth activity, (5) physical disorder and order, and (6) social disorder and order. The instrument also includes categories on ecologic features of the social, built and natural environments known as salutogens and pathogens. Salutogenic features include e.g., good housing quality, medical facilities, schools, green space, supermarkets, sewer and water infrastructure, equitable and just transportation networks, social service organizations (100). Pathogenic features include social pathogens (e.g., poverty, racism, crime,), food pathogens (fast food restaurants, liquor stores), economic pathogens (payday lenders, pawn shops), and environmental pathogens (e.g., landfills, industrial hog operations, coal ash ponds, incinerators, hazardous waste sites, heavily trafficked roads). Eligible blocks will include those that community members indicate an interest in due to concerns about the proximity of environmental hazards. We will especially consider blocks close to various public use areas where children and elderly individuals congregate based on feedback from community leaders and the Community Advisory Board (CAB, see Community Engagement Plan for more details). We will also collect sociodemographic data for each study community at the block, census block group, and census tract level from the 2010 US Census. We will collect data on race/ethnicity (% Black, % non-White, % Hispanic); income (median household income; % poverty, Townsend deprivation index); education (% less than high school education, % college graduate); age (% children, % elderly); sex (% male, % female); and other variables including % unemployment, % manufacturing, % homeowners, and mean age of home. We will map census data using ArcGIS 10.6 (Esri International, Redlands, CA). Statistics of the average and aggregate scores generated from the block assessment will be generated by racial and SES profiles within and across communities to assess the association between SES and vulnerability as measured by the number and concentration of salutogens and pathogens (100, 101).

Objective 3. Assist community partners in developing management and readiness plans. Once we have a working model relating source site characteristics and natural hazards to contaminant releases, exposures, vulnerabilities, and health risks, we will conduct focus groups with neighborhood residents and community partners in both study communities to evaluate scenarios of interest to community members (**Figure 7**).

Focus groups will complement interview and survey data to more fully identify disaster-related concerns, environmental justice and health issues, and potential areas for improvement related to community resilience planning and disaster readiness programming, and to explore a suite of different disaster scenarios and customized readiness plans for these scenarios. These scenarios

will encompass: (a) future climate change conditions (e.g., increased precipitation, hurricanes, heat, etc.), (b) possible technological/ industrial interventions (e.g., improved containment or emergency response practices), (c) possible social interventions (e.g., improved evacuation, information, or post-event practices), or (d) a combination of these. The focus groups will be conducted in collaboration with community partners using approaches that have previously been employed by our team. We expect to complete 2-3 focus groups in each study community consisting of 8 residents/group. The goal is to create combinations of model inputs and/or conditions that we can evaluate with our model and present back to the community to use in planning and decision-making. Our intent is to generate a feedback loop of knowledge transfers between researchers and engaged partners will be created to: (1) fully understand the extent of risk facing the community, (2) align research goals with the community's vision of environmental justice, (3) disseminate new knowledge in culturally appropriate frames, and (4) position community partners to act on a set of strategies grounded in empirical reality.

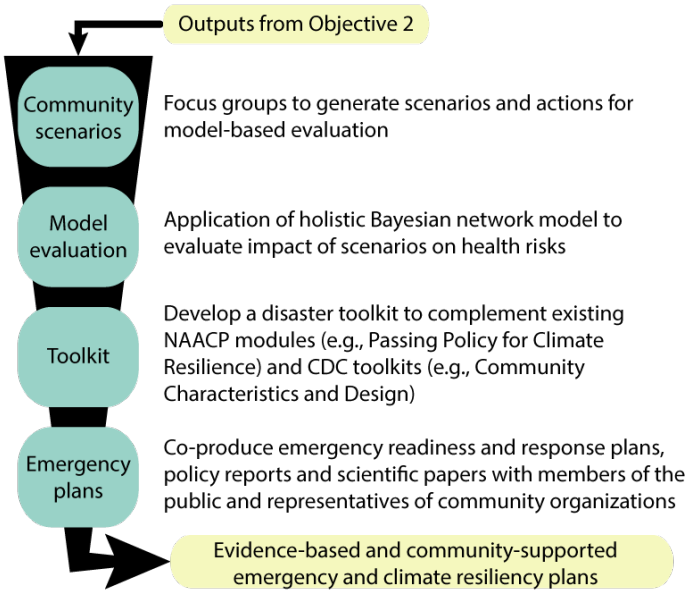

Figure 7: Workflow and expected resources for Obj. 3.

<u>Disaster Readiness Toolkits.</u> Core messages about NaTech disasters and disaster readiness will be developed into a toolkit using information on stakeholder attitudes, behaviors and social factors gathered from groundtruthing, interviews, and community science efforts (community-engaged maps, walking tours, Photovoice, and block assessments), disaster scenario development, and feedback from the CAB **(See Community Engagement Plan for more details)**. In these efforts, we plan to draw on and expand on existing tools and resources, including the NIST Community Resilience Planning Guide (102) and the NAACP Climate Change Adaptation Action Toolkit (103). Additionally, the U.S. Climate Resilience Toolkit (CRT) (104) provides a variety of tools to assess storm surge, flooding, and environmental change which can be utilized in conjunction with the mapping performed in Objective 2. The use of these tools will provide residents with information about their communities and resources. The combination of these toolkits will provide the resources needed to transform our risk analysis model into strategies to prevent or lessen the impacts of future disasters.

Core messages developed during collaborative scenario planning and toolkit development will be integrated into a larger recognizable campaign and appropriately formatted for a range of media venues (e.g., websites, Facebook, news media, fact sheets, radio spots, cable TV, public transports). These messages and related disaster readiness tips will be distributed in Year 3 as a toolkit. Half of the households that were surveyed in Objective 1 will be randomly selected to receive targeted household-scale education outreach, including educational print media and active in-person outreach from community partners and trained community scientists. Favored messages and favored formats will be identified and improved based on informal stakeholder

input (e.g., CAB, LAMC, CCRAB, REACH, and NCEJN), outputs from quantitative modeling, and review of disaster scenarios. To better understand integration and long-term behavior change related to disaster preparedness, households that were selected to receive targeted education and outreach will be contacted for a brief phone survey after hurricane season in Year 3 to understand whether the targeted education and outreach resulted in behavior change related to disaster readiness. This is critical to gaining a better understanding of gaps between awareness, knowledge and behavior change in communities vulnerable to NaTech disasters.

INNOVATION. There exist many screening tools to identify communities that may be at elevated risk of exposures to chemical and biological contaminants and to natural hazards. However, these tools are of limited value in screening vulnerabilities to NaTech events, which introduce new chemical exposure pathways and profoundly impact the applicability of readiness and response plans. We reconceptualize NaTech risks as a Bayesian network of interacting hydrometeorological, environmental, epidemiological and social phenomena. By developing a quantitative, probabilistic modeling framework, we can model human health endpoints of interest as the outcome of processes conditioned on individual and policy decisions. This will create a powerful tool for understanding the relative impact of physical and social vulnerabilities and guiding decision-making. Structuring emulations of relatively computationally demanding models within a Bayesian framework allows the possibility for scaling the framework developed here into regional or national screening tools. Current approaches in disaster prevention, readiness, and response embed a variety of assumptions about hazard priorities and individual response to public safety interventions such as evacuation orders. Individual and collective response to these interventions is poorly understood and is often lower among the groups who are already most vulnerable. **By building community engagement into our entire research and policy dissemination workflow, we strive to create both research that is responsive to the needs of frequently overlooked communities and policy advice that is realistic.** Available evidence suggests that policy and research products developed in collaboration with affected communities lead to enhanced trust and greater adherence, yet this is rarely done. We therefore view the co-execution of our research and policy activities as an innovative strategy to improve overall resilience to NaTech events.

SUSTAINABILITY. An increase in hydrometeorological hazards is triggering increasingly frequent releases of chemicals and pathogens, posing a threat to the environment and human health. Industrial containment, readiness, and response plans make assumptions about infrastructure integrity and environmental behavior that are violated by natural hazards and hence are less and less applicable. These events surprise policymakers and individuals who face a lack of tools to anticipate and prepare for these increasingly common synergistic risks. Our project delivers tools that will help prioritize investment in safety infrastructure and reduce exposure to biological and chemical contaminants. By co-producing science with vulnerable communities, we create awareness of environmental hazards and strategies to minimize risks and increase the likelihood that emergency response advice will be realistic and will be followed. These efforts combine to mitigate overall environmental injustices. Finally, by reducing the likelihood of community abandonment or relocation, we are contributing to the stability of local social and economic networks. **Overall, we strive to develop tools that have significant impacts on the environmental, social and economic dimensions of sustainability.**

EXPECTED RESULTS, BENEFITS, OUTPUTS AND OUTCOMES.

Specific ***results*** of this project are expected to include:

- Holistic model-based assessments of NaTech-associated contaminant risks for two communities subject to future environmental change.
- Articulation of alternative contaminant transport pathways and their dependence on natural event intensity.
- Quantification of the additional risks borne by vulnerable populations, including low-income families, children, and the elderly, resulting from currently overlooked vulnerability factors.
- A collaborative, interdisciplinary research team of junior and senior academics and community partners with the capacity for future community-engaged research projects.

Transferable ***outputs*** and ***work products*** include:

- A generalizable, modular tool to evaluate risks of contaminant exposures to under diverse natural hazard conditions and scenarios**.**
- Demonstration of how Bayesian networks can exploit emulation methods to integrate multiple models for holistic risk assessment.
- A characterization of potential vulnerability to contaminant releases as a function of relevant social, nutritional and other relevant variables.
- A toolkit to improve community resilience through risk mitigation activities, such as awareness campaigns, health promotion, and emergency readiness plans, co-developed with community partners.
- Peer-reviewed publications and conference presentations sharing our results and experience in the development and application of the project's methods and models.

Project ***benefits*** and ***outcomes*** will include:

- Enhanced readiness of communities to natural-disaster-driven contaminant exposures.
- Mitigation of environmental injustices through equitable and just planning processes.
- Better quality and length of life in vulnerable urban and rural populations subject to environmental contamination.
- Partner organizations and community members with skills and experience in collaborative research and resilience planning.

PROJECT MANAGEMENT. To ensure progress and success of the project, we will employ both a *Performance Management Plan* and an *Evaluation Plan*. The performance management plan will be used to: identify the resources (e.g., personnel, funds, data, tools, and software) necessary to accomplish each component; articulate the activities (e.g., data analysis, programming, workshops, and surveys) that need to be completed for each component; coordinate the timing, workflow, and linkages among components; and delineate the outputs/deliverables of each component. The evaluation plan will be designed to: enhance project implementation and operations; determine the success of the project in performing the planned activities, producing the planned outputs, and achieving the desired outcomes; document what the project has accomplished; and demonstrate accountability. Regular review of these plans will be used to improve the effectiveness and efficiency of ongoing activities or determine the need for additional activities. Development of these organizational and evaluative tools will be the first task should the proposed project be selected for funding.

Personnel. **Mark Borsuk** (Contact PI, Duke) and **Sacoby Wilson** (Co-PI, UMD) will jointly coordinate and supervise all project activities. Between them, they have successfully managed multiple EPA STAR, NIH, NIEHS, and NSF research grants. Borsuk is Associate Professor of Engineering and has multiple areas of research expertise directly relevant to this project, including: environmental and water quality modeling, Bayesian networks for decision support, expert and stakeholder engagement, and multi-criteria decision analysis. Wilson is Associate Professor at the Maryland Institute for Applied Environmental Health (MIAEH), UMD-College Park with expertise in exposure assessment, environmental justice science, social epidemiology, environmental health disparities, built environment, community resiliency, and community engagement including community-based participatory research (CBPR) and crowd science. Borsuk will lead the Bayesian network environmental modeling and Wilson will lead the environmental health assessment and community engagement aspects of the project. **Marccus Hendricks** (Co-I, UMD) is Assistant Professor of Urban Studies and Planning with research interests in infrastructure planning and management, social vulnerability to disaster, environmental justice, risk analysis, sustainable development, public health and the built environment, and participatory action research. Hendricks will be responsible for developing and implementing participatory actions, methods, and modeling. **Ryan Calder** (Post-Doc, Duke) is experienced in water quality, epidemiological, and toxicokinetic modeling. Calder will be responsible, along with a graduate student, for developing quantitative environmental, epidemiological and toxicological models used in the Bayesian network and will support community engagement efforts as required.

Project Timeline. Grey rows indicate major tasks and responsible leadership. Initials indicate team member(s) responsible for each task: B=Borsuk, W=Wilson, H=Hendricks, C=Calder, GS=Graduate Student.

	Year 1		Year 2		Year 3	
Task	I	II	I	II	I	II
Team coordination and leadership	Borsuk, Wilson					
Semi-annual team meetings	All	All	All	All	All	All
EPA STAR progress meetings		B, C		W, H		B, W
QAQC, Human Subjects, and Data Plan review		All		All		All
Objective 1	Borsuk, Calder					
Develop Bayesian network of NaTech events	B, C, GS					
Identify and link existing tools and models		B, C, H, GS				
Ground-truth model with community		H, W, B, C				
Objective 2	Wilson, Hendricks					
Identify exposure pathways/vulnerable pops.	W, H					
Identify modif. factors and dose-response			B, W. C			
Calculate and communicate current health risks			B, W, H, C, GS			
Objective 3	Wilson, Borsuk					
Formulate scenarios of interest				W, H, B		
Evaluate health risks under scenarios					B, W, H, C, GS	
Co-produce management and response plans					W, H, B, C	

QUALITY ASSURANCE STATEMENT

1. RESPONSIBILITIES

PI Mark Borsuk, will perform overall Project QA/QC oversight. Borsuk is an Associate Professor of Engineering with 15+ years of experience in modeling, analysis, and QA/QC of secondary data, including numerous EPA and NSF-sponsored projects. He has also been responsible for overseeing the collection and management of primary data resulting from multiple stakeholder workshop and survey efforts. As Community Engagement Core Leader for the Dartmouth Superfund Research Program, he has experience in developing, complying with, and reporting logic models, performance management plans, and evaluation plans.

2. PROJECT OBJECTIVES AND METRICS FOR SUCCESS

Project objectives are described in the main text and include: (1) development of a screening tool to estimate possible NaTech-related contaminant distributions in the environment; (2) development of an exposure modeling tool to describe how these possible future environmental concentrations are likely to impact health; and (3) co-production of disaster readiness and response guidance with communities retained as case studies using guidance from our modeling efforts. We will consider the project a success if: (1) we can provide informed advice to the communities we have retained as case studies; (2) describe a methodology for expanding our framework into a broader regional or national disaster vulnerability screening tool; (3) train student researchers in environmental risk modeling, environmental justice, community-engaged research methods, and development of toolkits; and (4) enhance our capacity for preventing, finding and correcting data entry, analytical and reporting errors. The success of individual project personnel is measured within the scope of annual performance evaluations. We will track progress toward these goals according to the Project Management Plan described in the Project Description.

3. DATA COLLECTION AND ANALYSIS

The overall goal of the project is to enable eventual extension of our framework into a regional or national disaster vulnerability screening model. Therefore, to the extent possible, we will rely on nationally available public datasets (e.g., the U.S. Census and the Toxics Release Inventory) that have already undergone quality control and analysis for accuracy, representativeness and other characteristics. We do not anticipate primary collection of quantitative data or chemical analysis of environmental samples.

The project will involve substantial use of probabilistic and statistical methods, notably, to parameterize a Bayesian network with relationships derived from mechanistic environmental models and parameterizing dose-response relationships from previous epidemiological investigations. However, none of the statistical work done in the scope of this project will be hypothesis-driven, and we therefore have no standards for statistical significance or power.

Primary data collection activities will be limited to interviews, surveys, focus groups, Photovoice, block assessments, citizen science training, and dissemination activities with community members and representatives of community-based organizations. These data will be largely qualitative in nature and will inform development of scenarios; serve as an evaluation of the relevance of the sites and contaminants we retain for quantitative evaluation; and used in the development of disaster readiness and community resilience toolkits. These data will be collected, retained, coded and communicated among project personnel in compliance with requirements of the research protocol reviewed and approved by the Institutional Review Board (IRB) of Duke University and/or the University of Maryland. Personally identifying data will not

be published (but may be aggregated) and will be retained for five years after project completion as described in the Scientific Data Management Plan.

4. USE OF SECONDARY DATA

We anticipate substantial collection, synthesis and manipulation of secondary data from public datasets. In the Project Description, we have described several data sources that we will likely rely on (e.g., the Toxics Release Inventory, the U.S. Census). At the beginning of the project, we will evaluate the range of other data sources that may be useful. This will include notably a review of data clearinghouses including EPA's Environmental Dataset Gateway and data.gov. We will target data sources with wide geographic availability in keeping with the Project goal of developing a framework that can be extended regionally or nationally.

Specific quantities of interest relate to: chemicals in use at industrial facilities (type and quantity), chemical releases into the environment, hydrometerological data (notably wind, storm surge and flooding) and population data (demographic details and information on factors that may imply vulnerability to risk, e.g., food insecurity).

Short-term data needs will cover the geographic extent of our case studies (i.e., Duplin County, NC and North Charleston, SC). In keeping with our goal of developing a regionally or nationally applicable framework, we will structure our analysis around datasets that are available at the national level. All data sources we anticipate using have undergone thorough quality control checks and have detailed guidance on representativeness and completeness (e.g., the U.S. Census).

In the Scientific Data Management Plan, we describe our plans for preservation of secondary data used in the analysis and preservation and publication of secondary data that we substantially manipulate or synthesize into new datasets.

5. METHOD DEVELOPMENT

The project does not involve the use or development of any chemical analytical methods. All environmental data will be retrieved from databases as described above. The development of statistical methods is described in the Project Description.

6. DEVELOPMENT OR REFINEMENT OF MODELS

The project involves: (1) implementation of existing environmental simulation tools; (2) programming of integrated environments for physical and statistical processes; and (3) statistical programming to develop relationships between (and among) environmental, toxicological and toxicological data. Project personnel involved with programming will follow best practices for model development outlined by the US EPA (105).

Many such best practices are facilitated by the modular, Bayesian network approach we envision here. For example, we will perform model evaluation on publicly available software packages individually before nesting emulated models within a Bayesian network. Project personnel include several individuals with expertise in water quality modeling and probabilistic modeling, enabling a system of mutual oversight and code verification.

The project envisions modeling environmental systems under scenarios for which there exist little to no empirical data, notably, hypothetical chemical releases under hypothetical natural hazard conditions. This limits the ability to which deterministic models can be validated or evaluated against empirical data. In previous work, we have shown how comparatively limited opportunity for model evaluation can be complemented with probabilistic modeling of emulated models to characterize the wide range of unknown future outcomes (38, 86). We intend to apply the same techniques here.

In the attached Scientific Data Management Plan, we describe our plans for long-term retention of final data generated by the Project and the reproducibility of interim data generated by environmental models.

7. DEVELOPMENT OR OPERATION OF ENVIRONMENTAL TECHNOLOGY

The project does not involve development or operation of environmental technology.

8. CONDUCTING SURVEYS

We will conduct interviews with members of the public and representatives of community-based organizations. We plan to undertake these activities in order to evaluate the qualitative relationship between our proposed activities and community needs and to understand the plausibility of potential scenarios, emergency readiness, and/or responsive advice. We may report simple statistics to describe variability in opinion among people we interview, but we do not intend to make any claims about generalizability. We do not intend to perform hypothesis-driven statistical analysis on any data collected in qualitative surveys.

9. DATA MANAGEMENT ACTIVITIES

In the Scientific Data Management Plan, we describe our plans to use open-source and/or freely available software and save all project output in formats that are accessible to anyone with sufficient computing resources and expertise. We also describe our plans for retention, publication, and stewardship of data.

HUMAN SUBJECTS RESEARCH STATEMENT

1. RISKS TO HUMAN SUBJECTS

a. Human Subjects Involvement, Characteristics, and Design

Describe and justify the proposed involvement of human subjects in the work outlined in the Research Strategy section. In order to assist communities in developing comprehensive strategies for building resilience to contaminant releases associated with NaTech disasters, we need to engage them and co-create quantitative risk models and tools. As part of this process, we need to engage communities to groundtruth the models, provide details on vulnerable populations and missing risk factors, verify if the models are realistic for vulnerable communities and populations (e.g., children, elderly), and collaborate on disaster scenarios and the development of disaster readiness and resilience toolkits.

Describe the characteristics of the subject population, including their anticipated number, age range, and health status, if relevant. The study population will come primarily from Duplin County, NC and neighborhoods associated with the Low Country for Model Communities (LAMC) and the Charleston Community Research to Action Board (CCRAB) (Union Heights, Accabee, Chicora/Cherokee, Green Grove, Liberty Hill, and Rosemont) in North Charleston, SC. Populations that live in these neighborhoods are primarily non-White, low SES (in regards to poverty and median household income) compared to the rest of country. We will recruit a total of 278 individuals (248 adults over age 18 and 30 youth between the ages of 12 and 17) to participate in project ctivities related objectives 1-3.

Describe and justify the sampling plan, including retention strategies and the criteria for inclusion or exclusion of any subpopulation. We will obtain a convenience sample of individuals who are residents of partner neighborhoods and are interested in participating in project activities. To participate in our qualitative research efforts and PPGIS trainings, a participant must be at least 18 years old, have lived in one of the study neighborhoods for at least one year, does not smoke, able to read and speak English, and healthy enough to perform field activities such as community-engaged mapping, PPGIS, Photovoice, and block assessments. The research team will work with staff of our community-based partners to train participants on how to develop community maps, perform block assessments, use EJSCREEN (PPGIS), and take photos during Photovoice activities. To participate in project activities, children must be at least 12 years old, have lived in a study neighborhood for at least one year, does not smoke, able to read and speak English, and healthy enough to participate in field exercises. As part of our retention strategy, we will provide incentives to participants including $25 for participating in interviews, focus groups, block assessments, and Photovoice. We will also provide incentives for participation in other project components (EJSCREEN training, disaster toolkit development).

Explain the rationale for the involvement of special vulnerable populations, such as pregnant women, children, or others who may be considered vulnerable populations. Children are included because children due to their age, development stage, and susceptibilities are at a high risk of injury, illness, and death due to NaTech disasters. It is important to include their perspectives and insight about environmental and natural hazards, vulnerability factors, and solutions for improved disaster readiness and community resiliency in the proposed project. Their inclusion strengthens the impact of the project.

List any collaborating sites where human subjects research will be performed, and describe the role of those sites and collaborating investigators. Explain how data will be obtained, managed, and protected. This research will be conducted primarily at study sites in North Carolina (Duplin County) and South Carolina (North Charleston). Community leaders

from LAMC, CCRAB, REACH, and NCEJN will have important roles in executing the goals and objectives of the project. LAMC and CCRAB will help with recruitment, engagement, and dissemination efforts in North Charleston and the state of South Carolina. While, REACH and NCEJN will help with recruitment, engagement, and dissemination efforts in Duplin County and the state of North Carolina (**see Community Engagement Plan for more details**). Dr. Borsuk will lead all disaster modeling efforts and assist with statistical analysis. Dr. Wilson will lead all community engagement efforts and collaborate with Dr. Hendricks on qualitative data collection, training, toolkit development, and dissemination efforts. More details on data management and protection can be found in this document and also the **Data Management and QA/QC Plans**.

b. Sources of Materials

Describe the research material obtained from living individuals in the form of specimens, records, or data. Describe any data that will be collected from human subjects for the project(s) described. We will obtain basic sociodemographic, family history data, lifestyle and behavior data, and health status data through eligibility and intake surveys. We will collect groundtruth data on quantitative risk models through community-engaged mapping and walks as part of Objective #1. We will collect additional data on NaTech vulnerability factors through interviews, surveys, Photovoice, and block assessments as part of Objective #2. As part of Objective #3, we will collaborate with community partners to translate research results from Objective #1 and #2 into products such as an updated EJSCREEN mapping tool and disaster readiness and community resilience toolkits. During these activities, we will collect data through focus groups, pre-and post EJSCREEN training questionnaires, and collaborative modeling of disaster scenarios. In addition, we will collect data on effectiveness of disaster readiness messaging for at-risk and vulnerable populations and communities during year 3 of the study.

Indicate who will have access to individually identifiable private information about human subjects. Drs. Wilson and Borsuk will have primary access to individually identifiable private information about human subjects. Additional access for partners may be provided in MOUs.

Provide information about how the specimens, records, and/or data are collected, managed, and protected. We will make the protection of the privacy and confidentiality of study participants a major priority in this study. Individual participants will not be identified in any reports including the community reports or peer-reviewed publications. Computer files will be maintained in password-protected databases, and computers will be turned off or otherwise disconnected from Internet access when not in use. All the information related to EJSCREEN (PPGIS) training will be de-identified, and data will be double-backed up and password protected. Audio recordings will be kept in digital format on password-protected databases. All log books that link a participant's name or address with his/her/they study number, completed surveys, pre-/post- training questionnaires, interview data, focus group data, Photovoice data, community-engaged mapping information, and block assessment data will be kept in locked file cabinet at either one of the PIs and/or shared with the community partners. This will be decided following CBPR principles and outlined in partner MOUs in the data management sections.

c. Potential Risks

Describe all the potential risks to subjects posed by participation in the research (physical, psychological, financial, legal, or other), and assess their likelihood and seriousness to the human subjects. This is an observational study being conducted to build new quantitative risk models that can be used to improve readiness and resilience to NaTech disasters in vulnerable communities. Participants may have an increased chance of exposure to contaminants associated with industrial hazards if they live in an area with industrial hog farms, storage tanks, Toxic

Release Inventory (TRI) facilities, or other hazards that may be emitting toxicants to the air that participants can breathe while performing Photovoice, mapping activities, walkthroughs, or block assessments. There may be some psychological risk to participants when completing surveys, interviews, or attending focus groups that may evoke memories of traumatic experiences during past natural disasters. There is a small risk of participants becoming stressed if and/or when they discover high pollution levels in their neighborhoods due to block assessment activities or training on the updated EJSCREEN mapping tool. Additionally, participants in the interview, Photovoice, and focus group sessions will be recorded and may feel uncomfortable during the sessions. There are no other anticipated risks to study participants.
Where appropriate, describe alternative treatments and procedures, including the risks and potential benefits of the alternative treatments and procedures. Not Applicable.

2. ADEQUACY OF PROTECTION AGAINST RISKS

a. Recruitment and Informed Consent

Describe plans for the recruitment of subjects (where appropriate) and the process for obtaining informed consent. If the proposed studies will include children, describe the process for meeting requirements for parental permission and child assent. LAMC, CCRAB, REACH, and NCEJN have a long history of working with EJ communities. Thus, our recruitment approach will not be random but from a convenience sample which is an appropriate methodology for CBPR. The study will be presented at partner meetings and events, meetings at local churches, mosques, community centers, barber shops, beauty salons, ethnic food stores, local health centers, and other sites to recruit and inform residents about the study. In addition, each partner will share information about the study at their monthly meetings and CAB members will share details about the study with their networks. We will interview potential participants to determine eligibility via telephone or person-to-person. We will obtain verbal consent using a standardized script for information on study eligibility. We will then obtain written consent for all residents eligible and interested in participating in the project. We will develop an assent form for children (12-17 years old) and their parents that will explain the project's goals and objectives, the data collection duties of the children, risks, and benefits. Both children and parents will be asked to sign this form. We will utilize a consent form to obtain parental or guardian approval. If the child does not provide assent and/or the parent does not provide consent, we will not pressure the child to participate.
Include a description of the circumstances under which consent. See above section.
If a waiver of some or all of the elements of informed consent will be sought, provide justification for the waiver. We will not ask any participant to waiver any elements of informed consent. Documentation of consent will be sought and maintained for each participant.

b. Protections Against Risk

Describe planned procedures for protecting against or minimizing potential risks, including risks to privacy of individuals or confidentiality of data. See following.
Research involving vulnerable populations, as described in the EPA regulations, Subparts B-D, must include additional protections. Children will be included in this study. We plan to have children participate in Photovoice, block assessments, and PPGIS activities. These activities will be organized with the help of community leaders and consultants with CCRAB, LAMC, REACH and NCEJN. This research will not involve greater than minimal risks to the non-adult participants. Parents will be encouraged to support their children as they participate in these activities. Only children between the ages of 12 to 17 will be asked to participate in these activities because of their time-intensive nature.

Additional Protections for Pregnant Women and Fetuses Involved as Subjects in Observational Research. We will not recruit pregnant women to participate in this study.
Additional Protections for Children Involved as Subjects in Observational Research. In order to minimize the risk to children of exacerbation of any existing ailments such as asthma, non- adult participants will be told to refrain from participating in Photovoice activities, block assessments, or PPGIS during certain periods of the day, such as when traffic is heavy, to minimize exposure to air pollutants, when the temperature is elevated, or during rainfall events to avoid flooded areas including flooding near industrial pollution sources.
Where appropriate, discuss the plans for ensuring necessary medical or professional intervention in the event of adverse effects to subjects. The only adverse effects to subjects that we can anticipate may be psychological stress if participants discover there are high levels of pollution in their communities or have experience trauma related to a prior NaTech disaster, or experience some discomfort while participating in the community-engaged mapping, walks, block assessments, and Photovoice activities. Any person including non-adults who exhibit emotional distress in any portion of the study will be referred to a health professional. The research team will not cover the cost associated with such services and participants will be made aware of this stipulation when the referral is made.

3. POTENTIAL BENEFITS OF THE PROPOSED RESEARCH TO HUMAN SUBJECTS AND OTHERS

Discuss the potential benefits of the research to the research participants and others. This study will increase community capacity to address local environmental health issues, increase expertise in community-based disaster management and response, provide environmental education opportunities, and enhance ability of community members to use scientific research in support of environmental policy and decision-making related to disaster management and community resilience. Policymakers will have more tools and data to improve their local-level disaster readiness and response plans particularly as they pertain to vulnerable communities such as those impacted by environmental injustice and vulnerable populations (e.g., children, elderly).
Discuss why the risks to subjects are reasonable in relation to anticipated benefits. This research will not involve greater than minimal risks to youth participants. We believe that any minor risks which may be possible are reasonable in relation to anticipated benefits.

4. IMPORTANCE OF THE KNOWLEDGE TO BE GAINED.

Discuss the importance of the knowledge to be gained as a result of the proposed research. Information gained from this research will significantly increase our understanding of risk of contaminant exposures to vulnerable communities and populations under diverse natural hazard conditions and scenarios in both urban and rural settings. This study will provide a useful framework for engaging communities in disaster research and the development of customizable disaster readiness and community resilience plans. The knowledge is also important to policymakers and disaster management and response agencies such as FEMA, Homeland Security, the US EPA, state agencies and county agencies including health departments and planning commissions who can use this knowledge to make their communities more resilient.
Discuss why the risks to subjects are reasonable in relation to the importance of the knowledge that reasonably may be expected to result. We seek to maximize the beneficence of this project for individuals who participate and the communities that live, work, pray, and play in as outlined in the principles of community-based institutional review boards (IRBs). For this reason, we believe the knowledge gained outweighs the risks to individual participants including adults and youths who currently live in communities with infrastructure issues, a history of NaTech disasters, and/or environmental justice and health issues.

SCIENTIFIC DATA MANAGEMENT PLAN

1. TYPES OF DATA TO BE GENERATED AND COLLECTED. Environmental and aggregated population data: We anticipate synthesizing data from government databases as described in the Research Plan. The overall goal of the Project is to facilitate development of a regional or national disaster vulnerability screening tool. Therefore, to the extent possible, we will rely on national, publicly accessible and quality-controlled electronic databases (e.g., Envirofacts, TRI Explorer, the Right-to-Know Network, U.S. Census). Some data (e.g., disclosures under EPCRA) may be publicly available but not available electronically. This may require collection of paper records and manual coding of data. We will assume responsibility for quality control of these data and apply best practices for data entry (see Quality Assurance Statement). Substantial data will be generated by open-source and/or freely available environmental models. We will not rely on any proprietary environmental modeling software. These data may be further transformed, for example, to parameterize statistical models. We consider freely accessible, previously collected data pertaining to individuals (e.g., from the U.S. Census) to fall outside the scope of our human subjects review requirements as these data have been anonymized, and we have not been involved in data collection or dissemination. Human subjects data: We will collect data on risk factors, environmental hazards, natural hazards, model validation, groundtruthing of outputs, vulnerability, perceptions of disaster preparedness and resilience, collaborative scenarios, and disaster readiness toolkits from members of the public and representatives of community-based organizations using questionnaires, survey instruments, interviews, Photovoice, block assessments, focus groups, dissemination events, and other qualitative approaches. All materials used to elicit information from individuals and the scope of all interactions will be subject to review and approval by the Duke University and/or University of Maryland (UMD) Institutional Review Board (IRB).

2. LOCATION OF DATA. All data will be maintained on secure servers at Duke University and/or UMD in folders accessible only to project personnel. Both institutions have departments responsible for the integrity, security, and reliability of data using the latest technologies.

3. STANDARDS FOR DATA FORMAT AND CONTENT. All data associated with the environmental modeling components of the Project will be archived in non-proprietary, open formats such as NetCDF, ascii tabular, and geoTIFF file formats. Using non-proprietary and open source formats will assure future accessibility of the data. All data will be packaged with associated metadata, including versioning, units, input data types, and scenario specifications. Metadata will be compliant with established guidelines such as Ecological Metadata (EML). Some proprietary software (e.g., Microsoft Word) is likely to be used during the course of project activities, but all modeling components will be in file formats that are accessible by anyone with available computing resources and expertise.

4. PLANS FOR DATA STORAGE, SHARING, ACCESS, AND VALIDATION. Making the results of our research available to a wide audience will be a priority. We plan to publish the results of our work in a timely manner in peer-reviewed scientific publications with sufficient documentation to allow anyone else to reproduce the results. We will also release our code, output, and QA/QC procedures for public use by posting them on a publicly accessible website after publication in the peer-reviewed literature or one year following completion of the Project. In the interim, data will be made available upon request at the discretion of the investigators. The documentation will be understandable by academic researchers, government officials, public health professionals, policymakers, members of community-based organizations, and lay populations. To ensure this, we will discuss the format and documentation in detail with community partners.

In addition to the above steps, we plan to disseminate the tools, approaches, and lessons of the project through other, more active, means, such as workshops and conferences hosted by the EPA and professional societies. Environmental data: All final data used to report findings in scientific articles or to develop community resources will be retained for a minimum period of five years and will be available by request. This includes datasets that we develop through manipulation or aggregation of multiple publicly available resources. To the extent allowed by scientific publishers, these data may also be included as supplemental information with journal articles. Any data we make accessible through an online interface will be retained for a minimum period of five years, and indefinitely thereafter, subject to periodic review of public and scientific needs and past usage. We will retain for a minimum period of five years all data collected from publicly accessible databases for the purposes of screening priorities or other informational purposes. Datasets that we do not substantially manipulate or synthesize will be publicly available by request, but we will not include such data with scientific publications or otherwise publish it.It is likely that a substantial amount of data will be generated by environmental modeling software. We will store these data for as long as needed to complete project activities in compliance with best practices for version control and file management. Human subjects data: Individually identifying data collected by project personnel will be stored on secure servers as described above and will be retained for a period of five years. No individually identifying information will be published. Aggregated data may be published in a way that is identifying to local communities or organizations, but this will be done in compliance with IRB research plans and with the informed consent of study participants. Any further use of human subjects data (otherwise than as previously published) will be subject to further IRB review and informed consent on the part of relevant community organizations and/or individuals.

5. VALIDATION OF DATA NOT PUBLICLY AVAILABLE. The only data generated by the project not publicly available relate to human subjects. Individuals and community-based organizations that produced these data will however be involved in all stages of the research and translation of the findings following the community-based participatory research (CBPR) framework. Therefore, interpretation of this data by project personnel will be continuously validated by its sources through feedback loops. Data that may not be retained long-term are limited to raw output of environmental models. Because we intend to use publicly available data and open-source and/or freely available modeling tools, this output should however be reproducible by anyone with available computational resources and expertise.

6. ROLES AND RESPONSIBILITIES FOR IMPLEMENTATION. PI Mark Borsuk (Duke) will have primary oversight and coordination responsibility for software and data generated within the scope of the proposed project, and will assume responsibility in the event that any Project personnel should change institutions or leave the Project. PI Sacoby Wilson will have primary responsibility for collection, preparation, and retention of individually identifiable human subjects data. Lead authors of scientific manuscripts, presentations, and policy documents will have primary responsibility for managing and retaining word processing and summary data relevant to these products on secure servers with regular backups at Duke University and UMD.

7. RESOURCES AND CAPABILITIES. Personnel have access to workstations with word processing, statistical and mathematical computing software (e.g., MS Office, Matlab, R). Duke Information Technology provides a networked file service with secure backups of all files. Duke Research Computing provides access to high-performance computing resources and support. We will rely primarily on open-source and/or freely available statistical and environmental modeling software and datasets whenever possible.

COMMUNITY-ENGAGED RESEARCH (CENR) PLAN

1. COMMUNITY PARTNERS.

Low Country Alliance for Model Communities (LAMC). In response to the planned expansion of the Port of Charleston and numerous community concerns, in 2005, several residents organized LAMC. LAMC focuses on improving health and quality of life in 7 economically distressed neighborhoods in North Charleston, SC with an emphasis in four core areas: 1) housing and revitalization, 2) workforce development, 3) education, and 4) environment. *The* ***Charleston Community Research to Action Board (CCRAB***) is a community-based organization dedicated to promoting environmental health and social justice solutions within the Charleston region particularly for burdened and underserved communities through the translation of research to action. CCRAB aims to 'inpower' residents to become more engaged in local environmental decision-making so they can contribute to the community resilience. ***Rural Empowerment Association for Community Help (REACH)*** was founded in the aftermath of Hurricane Floyd to support low-income families and people of color and continues to evolve to meet the needs of the local community and eastern North Carolina. The organization seeks to address the health effects of living close to industrial hog farms, problems stemming from mental and emotional oppression, economic inadequacies, employment and education needs, lack of single-family housing, racial and cultural imbalances, and limited youth programs and services. ***North Carolina Environmental Justice Network (NCEJN)*** is a grassroots, people of color-led coalition of community-based organizations and their supporters who work with low-income communities and people of color on issues of climate, environmental, racial, and social injustice.

Community Engagement Plan. The community engagement plan will primarily use elements of the community-based participatory research (CBPR) framework and collaborative problem-solving (CPS) model (106-119). Dr. Wilson has extensive experience using both in his work.

Current Partnerships. In 2007, LAMC and the University of South Carolina (USC) formed a partnership called the Charleston Area Pollution Prevention Partnership (CAPs)(PI: Dr. Sacoby Wilson). With funding from the National Institute for Environmental Health Science (NIEHS), CAPs has been able to expand its efforts to better understand the impact of port-related activities on air quality in the region. In subsequent years, the partnership added the University of Maryland-College Park, the Medical University of South Carolina, and several other Charleston area neighborhoods. Dr. Wilson has worked with LAMC on a number of community-engaged research efforts funded by NIEHS, NIMHD, and other sources as can be seen by the publication record (28, 63-65, 120-131). Dr. Wilson is currently working with REACH and NCEJN to develop a program to provide technical assistance and support to communities impacted by industrial hog farming and other industrial land uses in North Carolina and the Mid-Atlantic.

Building Equity into the Partnership. In CBPR, it is critical for partners to agree upon the terms of collaboration and ensure equity between partners including addressing social inequality. Studies have shown that there are power imbalances between researchers and community partners (132-136). To address these issues, the CAB will play a pivotal role in informing how the partnership operates and how the study is implemented. In collaboration with the CAB, REACH, CCRAB, LAMC, and NCEJN, we will develop MOUs that will outline the terms of collaboration, including: (1) co-design (and redesign as needed) of study questions, framework, and methods; and (2) co-generation of deliverables, data ownership, data sharing, and dissemination. As part of these MOUs, we will encourage community partners to outline specific roles and responsibilities they will have on the project. To address inequities in power distribution, we will encourage each partner organization to elevate a representative to the role of co-investigator on the project.

Additionally, we believe it is important to provide financial resources to community members participating in the project. This is a best practice of building partnerships and performing CBPR research. For this particular project, we have budgeted funds to: (1) cover incentives for participants participating in surveys, Photovoice, and focus groups; (2) provide a stipend for participation of community advisory board members; and (3) show that we value the participation of community leaders who will contribute significant person-hours to completing activities outlined in Objectives 1-3. These community leaders will be hired as community consultants. We have budgeted $25,000/year for this specific effort.

Community Advisory Board (CAB). As part of the CEnR plan, a community advisory board will be developed consisting of community members and leaders from REACH, NCEJN, CCRAB, and LAMC. Actualizing the principle that CBPR builds on the strengths and resources of the community, the CAB will play a major role in the proposed project. If funded, the CAB will be engaged in all stages of the research process including development of study design, methods, implementation, review, and dissemination. As part of project activities, the CAB will meet quarterly with the team to provide feedback on study design and CBPR issues. The CAB will also provide input via monthly conference calls and emails. In addition, the CAB will host a yearly 2-day retreats with the team to discuss issues and challenges related to trust, group conflict, power, and shared decision-making. We will discuss and select strategies for addressing these issues. The CAB will also help address any cultural concerns, language concerns, and compensation for study participants. CAB members will receive $1000/year.

Communication with Partners. In CBPR, trust is an essential component of successful community-university partnerships (132-139). Constant, consistent, bidirectional and open communication is essential for building trust. The research team will host monthly web meetings with partners including the CAB to discuss issues related to the project. In addition, there will be internal communication activities to ensure community leaders, board members, and partners are aware and understand what is occurring with project-related activities. These activities include regular check-ins; a Google Calendar to ensure that all activities, projects, and events are featured on a yearly calendar that can be electronically accessed; use of Microsoft Project to enhance the ability of project staff and volunteers to collaborate on project objectives via an electronic platform.

CBPR Evaluation. Dr. Wilson will lead this effort. We will employ CBPR evaluation tools used previously (110, 127, 139-143) including the NIEHS PEPH manual (144) following CCPH's Principles of Partnership (145). Through open discussion with the CAB during quarterly meetings and the annual 2-day retreat, we will assess how well we are: 1) following the guiding principles of partnership, 2) achieving quality processes, 3) creating meaningful outcomes, and 4) creating transformative experiences for partners and participants. A review of issues will occur during team calls and strategies for addressing partnership issues will be discussed, selected, and implemented.

2. OBJECTIVE 1 CORE COMMUNITY ENGAGEMENT ACTIVITIES.

Recruitment. LAMC, CCRAB, REACH, and NCEJN have a long history of working with EJ communities. Thus, our recruitment approach will not be random but from a convenience sample which is an appropriate methodology for community-engaged research particularly CBPR. Due to the strength of Dr. Wilson's long-term relationships with these groups, we believe convenience recruitment is the most appropriate recruitment methodology to help us reach our enrollment numbers and achieve the goals and objectives of our proposed project. The study will be presented at partner meetings and events, meetings at local churches, mosques, community

centers, barber shops, beauty salons, ethnic food stores, local health centers, and other sites to recruit and inform residents about the study. In addition, each partner will share information about the study at their monthly meetings. We will also work with advisory board members to share study information with their networks. Interested residents will be asked to call CCRAB for additional information about the proposed project. Study materials will also include self-addressed sealed envelopes that potential participants can return to the PI.

Community Groundtruthing. To ground truth local contaminant sources and exposure pathways, we will engage in mapping and community walks with residents in both study communities. **Community-engaged mapping** is a group mapping exercise designed to answer specific research questions and gather feedback from community members (who live, work, or attend school in the area). It can be described as a focus group around a map because residents dialogue over maps of a neighborhood about their experience with the local physical environment. In each study community, we will have small, breakout groups that allow select residents to collectively discuss and map their communities. This and other types of public participatory mapping approaches have been effectively used in previous work of the team (27, 28). ***A community walk*** is a method where community members walk through a neighborhood of interest to map out and collect information about their neighborhood's sites and social, economic, and cultural dynamics. It provides a first-hand view of the community, its people, and its sites and can naturally provide information needed to identify potential contaminant sources and exposure pathways. We will perform walking interviews to obtain detailed information about locations of concern. We will have participants take pictures of these locations which will placed on the co-created maps.

3. OBJECTIVE 2 CORE COMMUNITY ENGAGEMENT ACTIVITIES.

Photovoice. To give voice to youth perspectives on environmental hazards, disasters, community vulnerability, and community resiliency, and to compare youth perspectives with those of adults, we will use the innovative approach of Photovoice (91, 92) following similar approaches to those of prior projects by members of our team (93, 95, 123). Youth and adult cohorts will use Photovoice to capture their experiences related to environmental hazards and disasters in their communities following the SHOWeD method (96-98). Two groups of 15 participants will participate in two Photovoice sessions in each study community. Sessions will be recorded and transcribed verbatim. Upon identifying themes, data will then be coded and used to inform block assessments and Objective 3 activities.

Block Assessment. Our block assessment tool is an adaptation of the multi-item Neighborhood Inventory for Environmental typology (NIfETy) (99). The items on the assessment are operationalized in six domains including: (1) physical layout of the block face, (2) types of structures, (3) adult activity, (4) youth activity, (5) physical disorder and order, and (6) social disorder and order. The instrument also includes categories on ecologic features of the social, built and natural environments known as salutogens and pathogens (100, 146-150). Eligible blocks will include blocks that community members indicate an interest in having an environmental quality assessment done due to concerns about the proximity of environmental hazards such as industrial hog operations, coal ash ponds, Superfund sites, or brownfields. We will also consider blocks close to various public use areas where children and elderly individuals congregate based on feedback from community leaders and the CAB.

Objective 3 Core Community Engagement Activities.

PPGIS Training and Mapping. To build the capacity of local residents to assess vulnerability, local environmental health risks, and disaster readiness, we will train them in Public Participatory Geographic Information Systems (PPGIS) (27, 28). The PPGIS tool we will use in

this effort is the USEPA's EJ SCREEN tool. We plan to expand EJSCREEN's capacity for identifying and analyzing environmental justice communities at-risk from natural hazards by constructing a disaster vulnerability index using the following parameters: 1) Geo-political features, 2) landscape features, 3) household composition and disability, 4) minority status and language, 5) housing and transportation, 6) major human health indicators, 7) major watershed health indicators, and 8) mitigation indicators. We plan to leverage the Coastal Resilience Index (CCRI), the City Resilience Index (CRI), Rural Resilience Index (RRI), and the Hazard Resilience Index (HRI) (151-155). We will integrate the following parameters and related indicators into EPA EJSCREEN to produce a disaster resiliency score for environmental justice communities in Charleston, SC and Duplin County, NC: 1) Critical infrastructures and facilities, 2) transportation issues, 3) community plans and agreements, 4) mitigation measures, and 5) business information. For a complete list of relevant indicators, please see the US Climate Resilience Toolkit (69) and other indices previously listed.

As part of the PPGIS training, we will conduct three six-month workshop series (held sequentially from June to August 2021) on using EJSCREEN tool for community resilience planning and disaster readiness and management. Workshop topics will include: 1) Using EJSCREEN to Assess Risk from Natural Disasters for Susceptible Groups such as Children and the Elderly; 2) Using EJSCREEN to Map Disaster Resilience In Your Region; 3) Using EJSCREEN to Develop Disaster Readiness Plans Across High, Medium, and Low Risk Scenarios; and 4) Conducting Community-led Research on Risks from Natural Hazards and Disasters at the Local Level. Participants at the end of the workshops will be able to answer the following questions: 1) How pollution risk and population characteristics affect an area's disaster resilience and vulnerability; 2) How EJ Scores can be used to compare areas' levels of disaster resilience and vulnerability concern; and 3) How these comparisons can be utilized in resilience planning and disaster readiness programming. The audience will include community members and other stakeholders from the study communities. We will assess knowledge gained and PPGIS skills of workshop attendees through periodic pre-/post-test assessments and a benchmark assessment which will be given at the beginning of the first workshop and end of the final workshop. We expect to recruit and train 75 individuals/study area (n=150).

Disaster Readiness Toolkits. In our efforts to develop a disaster toolkit, we will expand on the previous work of community groups, government agencies, and non-profits and utilize existing tools and resources. The NIST Community Resilience Planning Guide (102) and the NAACP Climate Change Adaptation Action Toolkit (103) outline steps that encourage communities build relationships with stakeholders, assess the risks posed by disasters and the changing environments, set goals and objectives, and create and execute equitable action plans. Each of these steps are accompanied by a variety of guides and tools that can be applied by the community, in addition to the wide array of more specific toolkits at their disposal. For instance, when building relationships within the community, we will utilize the 'A Community Coming Together' module within the NAACP Climate Change Adaptation Action Toolkit (103) to assist with our interacting with communities when conducting research to ensure co-ownership of the work. The U.S. Climate Resilience Toolkit (CRT) (104) provides a variety of tools to assess storm surge, flooding, and environmental change which can be utilized in conjunction with the mapping application generated from Objective 2 to assist in the assessment of risks with the community. To incorporate information about housing access, roadways, important facilities, grocery store access and green space the CDC's National Environmental Public Health Tracking Network will be utilized (https://ephtracking.cdc.gov/). The use of these tools will provide

residents with information about their communities and resources. Additionally, the FEMA Flood Risk Communication Toolkit (156) and NIST Community Resilience Planning Guide (102), and NAACP Action Toolkit (103) have useful modules that will help to synthesize information about the risk they face. To develop and enact an effective disaster management, prevention, or mitigation plan, the NAACP's In the Eye of The Storm Action and Climate Adaptation Toolkits (51, 103) will be used. The combination of these toolkits provides the resources to transform risk assessment into implementation of strategies that may prevent or lessen impacts of future emergencies. Additionally, the toolkits are designed from an inclusive community perspective and incorporate equitable response, recovery, and management.

4. DISSEMINATION STRATEGIES

***Community Reports*.** Paper and electronic reports will be produced every project year and distributed to residents and other stakeholders. We will present results to the community following ethical report back principles (157, 158) that members of the team have followed in previous work. These reports will also be posted on project websites.

Annual Retreat. An annual retreat will be held for partners to work with CCRAB to discuss issues and challenges related to trust, group conflict, power, and shared decision-making. The team will also discuss lessons learned and best practices. Suggestions for how to improve the implementation of the CEnR plan including qualitative research efforts (surveys, interviews, community-engaged mapping, Photovoice, and block assessments), PPGIS training, and toolkit development will be discussed and adopted during this retreat.

Project Website. A website for disseminating information to the community will be jointly hosted by the CAB and community partners to ensure that results are shared with equitably and appropriately with vulnerable populations and groups at-risk from NaTech disasters.

***Sharing of Disaster Readiness Materials*.** Environmental justice research should ultimately have human outcomes in terms of improving community health, resiliency, quality of life, and social equity. Activities under Objectives 1-3 will be used to develop Disaster Readiness Toolkits that will be shared with community partners and other groups; county agencies; and state officials in North Carolina (DEQ and the North Carolina EJ Commission) and South Carolina (SC Department of Health and Environmental Control). These toolkits will be discussed at dissemination meetings in year 3. We will make policy recommendations for revisions to comprehensive plans, sustainability plans, resiliency plans, emergency response plans for both study communities on the issue of disaster readiness. Resultant policy changes will further promote social and environmental justice, equity in disaster planning and management, enhance community resiliency, promote community-driven disaster readiness, and facilitate reductions in negative impacts on health and quality of life due to NaTech disasters in these communities.

Refereed publications. We will publish our results in academic journals with community partners as co-authors. Manuscripts will be submitted to journals that support community engagement and CBPR including *Progress in Community Health Partnerships, Environmental Justice, American Journal of Public Health, and the Journal of Community Health.*

Conferences. During years 1-3, we will present information about the project including share research results at the annual Community-Based Environmental Justice Summit held by NCEJN in Bricks, North Carolina and annual EJ and Health Disparities Symposium held at the University of Maryland-Coll (organized by Dr. Wilson). Due to the proximity of academic and community partners in North Carolina, South Carolina, and Maryland, this conference is a good location for all partners to meet, but more importantly, an excellent venue to share results with members of other communities at-risk of NaTech disasters in the Carolinas.

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asthma-related health by reducing household environmental triggers for asthma" in *Health Educ Behav* 35(3): 376-395.
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BUDGET JUSTIFICATION

GRANT #G19E112942187 – DUKE UNIVERSITY

A. PERSONNEL

Position/Title	Annual Salary	% of Time Assigned to Project Cost	Cost
Principal Investigator	(b) (6)	6.66%	(b) (6)
Postdoctoral Associate	(b) (6)	16.66%	(b) (6)
Graduate Student	(b) (6)	75.00%	(b) (6)
		Total Personnel Year 1	**$43,044**
Principal Investigator	(b) (6)	6.66%	(b) (6)
Postdoctoral Associate	(b) (6)	16.66%	(b) (6)
Graduate student	(b) (6)	75.00%	(b) (6)
		Total Personnel Year 2	**$44,061**
Principal Investigator	(b) (6)	6.66%	(b) (6)
Postdoctoral Associate	(b) (6)	16.66%	(b) (6)
Graduate student	(b) (6)	75.00%	(b) (6)
		Total Personnel Year 3	**$45,290**
		Total Personnel	**$132,395**

Dr. Mark E. Borsuk, Principal Investigator: As PI, Dr. Borsuk will be responsible for coordinating and managing all aspects of the project. He will provide disciplinary expertise in environmental risk modeling, uncertainty analysis, and Bayesian networks and will mentor Duke team members on these aspects. Funding corresponding to 0.6 month per year of his summer salary in years 1–3 is requested to support his efforts.

Dr. Ryan S. Calder, Postdoctoral Associate: Dr. Calder is an expert in mathematical modeling of coupled social-natural systems and carrying out computationally intensive numerical simulations. He will be responsible for development of the mechanistic fate, transport, and exposure models and development of the Bayesian network integrative model. Funding corresponding to 2 months of his salary in years 1–3 is requested to support his efforts.

TBD, Graduate Student Researcher: Funds are requested to support a Graduate Research Assistant for 9 months in years 1 - 3. The Graduate Student will primarily work on data aggregation, analysis, and model application. The budget reflects wages for a Ph.D. student at Duke University. Ph.D. student wages are determined by the Graduate School at Duke in consultation with the faculty, department heads, deans, and the University administration, based on consideration of living costs and the competitive market for top-quality Ph.D. students.

Salaries for Duke personnel in years 2–3 are adjusted to reflect the average annual institutional staff salary increase of 3% per year.

B. FRINGE BENEFITS

In accordance with Duke University guidelines, the fringe benefits rate for Faculty salary is

(b) (6)

Position/Title	Salary	Fringe Benefits Rate	Cost
Principal Investigator	(b) (6)	(b) (6)	(b) (6)
Postdoctoral Associate	(b) (6)	(b) (6)	(b) (6)
Graduate Student - May to August	(b) (6)	(b) (6)	(b) (6)
Graduate Student - September to April	(b) (6)	(b) (6)	(b) (6)
Total Fringe Benefits Year 1			(b) (6)
Principal Investigator	(b) (6)	(b) (6)	(b) (6)
Postdoctoral Associate	(b) (6)	(b) (6)	(b) (6)
Graduate Student - May to August	(b) (6)	(b) (6)	(b) (6)
Graduate Student - September to April	(b) (6)	(b) (6)	(b) (6)
Total Fringe Benefits Year 2			**$7,885**
Principal Investigator	(b) (6)	(b) (6)	(b) (6)
Postdoctoral Associate	(b) (6)	(b) (6)	(b) (6)
Graduate Student - May to August	(b) (6)	(b) (6)	(b) (6)
Graduate Student - September to April	(b) (6)	(b) (6)	(b) (6)
Total Fringe Benefits Year 3			(b) (6)
Total Fringe Benefits			(b) (6)

C. TRAVEL

Total request for all years: **$7,500.**
Travel funds in the amount of $2,500 in years 1-3 are requested for PI attendance at the annual STAR program reviews and final workshop, as well as one trip per year by the Duke team to study sites.

Purpose	Location	Item	Computation	Cost
EPA STAR Progress Review	DC	Lodging	1 person x $150 per night x 2 nights	$300
		Airfare	1 person x $400 round trip	$400
		Per Diem	1 person x $50 per day x 2 days	$100
Study sites	NC, SC	Lodging	2 people x $150 per night x 3 nights	$900
		Auto	$500 round trip	$500
		Per Diem	2 people x $50 per day x 3 days	$300
Total Travel per Year				**$2,500**
Total Project Travel all Years -- $2,500 X 3				**$7,500**

F. CONTRACTUAL:

Consultant Services: Funds in the amount of $25,000 in years 1 – 3 are requested for community consultants to assist with outreach, recruitment, study implementation, and dissemination efforts, as described in the Community Engaged Research Plan. We will pay community consultants $50/hour and plan for an average of 250 hours per year in each of the two study regions. Consultants will come from local environmental justice organizations, including those identified in the proposal.

H. OTHER

Subawards: Total project cost of $372,325 ($121,069 in year 1, $121,252 in year 2 and $130,004 in year 3) are requested for a subcontract with University of Maryland, College Park. **Dr. Sacoby Wilson, Co-PI** will collaborate with Dr Marccus Hendricks, and both will be assisted by a Graduate Research Assistant. The University of Maryland team will be responsible for assessing and modeling community vulnerability and individual susceptibility within the context of the broader risk analyses. They will also be responsible for implementing the project's Community Engagement Plan.

Tuition Remission: Tuition remission costs are calculated using the University's "Average Rate Basis (ARB)" methodology which has been approved by our Federal Cognizant Agency (Department of Human and Health Services - DHHS). For the 2019-2020 academic year, tuition remission for Ph.D. research assistants is calculated at 37.3%. The Graduate School sets the rate and has projected future years rates of 37.7%, 38.4% and 39.1%. These rates are applied consistently across the University, regardless of funding source. For this project, one Ph.D. student is been budgeted for 9 months in years 1-3.

Position/Title	Salary	Tuition Remission Rate	Cost
Graduate Student - May to August	(b) (6)	37.30%	(b) (6)
Graduate Student - September to April	(b) (6)	37.70%	(b) (6)
		Tuition Remission Year 1	**$9,072.75**
Graduate Student - May to August	(b) (6)	37.70%	(b) (6)
Graduate Student - September to April	(b) (6)	38.40%	(b) (6)
		Tuition Remission Year 2	**$9,389.70**
Graduate Student - May to August	(b) (6)	38.40%	(b) (6)
Graduate Student - September to April	(b) (6)	39.10%	(b) (6)
		Tuition Remission Year 3	**$9,813.05**
		Total Tuition Remission	**$28,275.50**

J. INDIRECT COSTS

Indirect costs were calculated from the Facilities and Administrative (F&A) cost rate of 61% in years 1–3 determined for on-campus, federally-sponsored projects, as negotiated with DHHS. This percentage has been applied to the modified total direct costs (MTDC), equal to total direct costs minus capital equipment costs, Graduate Student Tuition Remission, off-site facilities rental fees, and sub-award costs exceeding $25,000 per sub-award.

K. TOTAL DIRECT AND INDIRECT COSTS: $799,756

BIOGRAPHICAL SKETCH

NAME: Borsuk, Mark Edward

POSITION TITLE: Associate Professor of Engineering

EDUCATION/TRAINING:

INSTITUTION AND LOCATION	DEGREE	Completion Date	FIELD OF STUDY
Princeton University, Princeton, NJ	B.S.E	06/1995	Engineering and Operations Research
Duke University, Durham, NC	M.S.	06/2001	Statistics and Decision Science
Duke University, Durham, NC	Ph.D.	06/2001	Environmental Science and Policy
EAWAG, ETH, Zürich, Switzerland	Post-Doc	12/2005	Systems Analysis and Integrated Assessment

A. Personal Statement

My research concerns the development and application of mathematical models for integrating scientific information on natural, technical, and social systems. I am especially interested in the representation of knowledge uncertainty in models used for prediction and decision-making. I am an expert on practical applications of Bayesian networks, with a focus on environmental and human health risk assessment. Additional areas of research include expert and stakeholder elicitation, multi-criteria decision analysis, probabilistic environmental forecasting, and methods of model sensitivity and uncertainty analysis. My highly collaborative research has been funded by NSF, EPA, NIH, NIEHS, DoD, and USFS, and I have authored or co-authored over 80 peer-reviewed journal publications and 6 book chapters. I teach undergraduate and graduate courses on optimization, engineering economics, modeling, statistics, and decision analysis. I will serve as Contact PI on the proposed project

B. Positions and Honors

Positions and Employment

2018 – present Co-Director, Duke Center on Risk, Duke University, Durham, NC
2016 – present Assoc. Professor, Civil and Environmental Engineering, Duke University
2010 - present Guest Investigator, Woods Hole Oceanographic Institution, Woods Hole, MA
2013 - 2016 Assoc. Professor, Thayer School of Engineering, Dartmouth College, Hanover, NH
2007 - 2013 Assistant Professor, Thayer School of Engineering, Dartmouth College
2006 - 2007 Research Asst. Professor, Department of Biological Sciences, Dartmouth College
2004 - 2005 Research Group Leader, Integrated Modeling and Decision Analysis, Department of Systems Analysis, Integrated Assessment and Modeling, Swiss Federal Institute for Environmental Science and Technology (EAWAG), Dübendorf, Switzerland
2001 - 2003 Post-Doctoral Researcher, EAWAG, Dübendorf, Switzerland
1997 Director, Governor's Working Group on Water Quality, Raleigh, NC
1995 - 1996 Engineering Associate, ENVIRON Corporation, Princeton, NJ

Other Professional Activities

2018 – present Council Member, Society for Risk Analysis
2016 – present Editorial Board: Integrated Environmental Assessment and Management
2014 – 2018 Steering Committee: Scenarios, Services, and Society (S3) NSF-RCN
2012 – 2016 Community Engagement Core Leader, Dartmouth Superfund Research Program
2010 – 2016 Associate Editor: Environmental Modelling & Software
2009 U.S. EPA Science Advisory Board, Expert Elicitation Advisory Panel

Awards

2018 Earl I. Brown Outstanding Civil Engineering Faculty Award, Duke University
2013 Chauncey Starr Distinguished Young Risk Analyst Award, Society for Risk Analysis
2012 Best Paper, Integrated Environmental Assessment and Management Journal
2010 Excellence in Mentoring Award, Dartmouth College Postdoctoral Association
2008 Best Paper in Integrated Modelling, Journal of Environmental Modelling and Software
2008 Early Career Research Excellence Prize, Int. Environmental Modelling and Software Society
2002 The Universities Council on Water Resources Ph.D. Dissertation Award
1999-2001 US EPA-STAR Graduate Fellowship
1996-2000 J.B. Duke Graduate Student Fellowship

C. Select Publications

Calder, R. S. D, C. Shi, S.A. Mason, L. P. Olander and **M. E. Borsuk**. 2019. Forecasting ecosystem services to guide coastal wetland rehabilitation decisions. *Ecosystem Services* 39: 1010072.

Murphy, M., G. Mavrommati, V. Mallampalli, R. B. Howarth, **M. E. Borsuk**. 2017. Comparing group deliberation to other forms of preference aggregation in valuing ecosystem services. *Ecology and Society* 22(4): 17

Samal, N., W. Wollheim, S. Zuidema, R. Stewart, Z. Zhou, M. Mineau, **M. E. Borsuk**, K. Gardner, S. Glidden, T. Huang. 2017. A coupled terrestrial and aquatic biogeophysical model of the Upper Merrimack River watershed, New Hampshire, to inform ecosystem services evaluation and management under climate and land-cover change. *Ecology and Society* 22(4):18.

Paul, M. P., P. Rigrod, S. Wingate, **M. E. Borsuk**. 2015. A community-driven intervention in Tuftonboro, New Hampshire, succeeds in altering water testing behavior. *Journal of Environmental Health*, 78: 30-39.

Chen, C.Y., **M. E. Borsuk**, D.M. Bugge, T. Hollweg, P.H. Balcom, D.M. Ward, J. Williams, R.P. Mason. 2014. Benthic and pelagic pathways of methylmercury bioaccumulation in estuarine food webs of the northeast United States. *PLoS ONE* 9 (2), e89305.

Turaga, R. M. R., R. B. Howarth, and **M. E. Borsuk**. 2014. Perceptions of mercury risk and its management. *Human and Ecological Risk Assessment* 20; 1385-14055.

Su, C., A. Andrew, M. Karagas, **M. E. Borsuk**. 2013. Using Bayesian networks to discover relations between genes, environment, and disease. *BioData Mining* 6:6 doi:10.1186/1756-0381-6-6.

Ding, P., M. D. Gerst, A. Bernstein, R. B. Howarth, and **M. E. Borsuk**. 2012. Rare disasters and risk attitudes: International differences and implications for integrated assessment modeling. *Risk Analysis* 32: 1846-1855.

Borsuk, M. E., S. Schweizer, and P. Reichert. 2012. A Bayesian network model for integrative river rehabilitation planning and management. *Integrated Environmental Assessment & Management*. 8: 462–472. ** Selected by the journal as Best Paper of 2012 **

Barton, D. N., S. Kuikka, O. Varis, L. Uusitalo, H. J. Henriksen, **M. E. Borsuk**, A. de la Hera, R. Farmani, S. Johnson, J. D.C. Linnell. 2012. Bayesian networks in environmental and resource management. *Integrated Environmental Assessment & Management* 8: 418-429.

Borsuk, M. E., P. Reichert, A. Peter, E. Schager, and P. Burkhardt-Holm. 2006. Assessing the decline of brown trout (Salmo trutta) in Swiss rivers using a Bayesian probability network. *Ecological Modelling* 192: 224-244.

Hostmann, M., B. Truffer, P. Reichert and **M. E. Borsuk**. 2005. Stakeholder values in decision support for river rehabilitation. *Archiv für Hydrobiologie* 155: 491-506.

Borsuk, M. E., C. A. Stow, and K. H. Reckhow. 2004. A Bayesian network of eutrophication models for synthesis, prediction, and uncertainty analysis. *Ecological Modelling* 173: 219-239.

Borsuk, M. E., R. T. Clemen, L. A. Maguire, and K. H. Reckhow. 2001. Stakeholder values and scientific modeling in the Neuse River watershed. *Group Decision & Negotiation* 10: 355-373.

BIOGRAPHICAL SKETCH

NAME: Wilson, Sacoby Miguel

POSITION TITLE: Associate Professor

EDUCATION/TRAINING:

INSTITUTION AND LOCATION	DEGREE	Completion Date	FIELD OF STUDY
Alabama A&M University, Normal, AL	BS	05/1998	Biology/Ecotoxicology
University of North Carolina, Chapel Hill, NC	MS	12/2000	Environmental Health
University of North Carolina, Chapel Hill, NC	PhD	05/2005	Environmental Health
University of Michigan, Ann Arbor, MI (Robert Wood Johnson Health and Society Scholars Program)	Postdoctoral Fellowship	07/2007	Social Epidemiology

A. Personal Statement

I will act as a Co-Investigator on the proposed project. I have over 15 years of experience in exposure assessment, environmental justice science, social epidemiology, health disparities, built environment, air pollution monitoring, and community engagement including community-based participatory research (CBPR) with over 70 peer-reviewed publications on these topics. I was the PI of a NIEHS-funded project with the Low Country Alliance for Model Communities (LAMC) entitled: "Use of a Community-University Partnership to Eliminate Environmental Stressors". I was Co-PI of an Environmental Health core at a NIMHD-funded health disparities P20 Center of Excellence at USC led by Dr. Saundra Glover. I was also the Co-PI of a NIEHS-funded R21 project that used CBPR to assess long-term impacts of a chlorine disaster in Graniteville, SC.

I will lead community engagement efforts including partnering with environmental justice groups in our two study areas and working with them to co-design and implement project activities. I currently work with LAMC and the Charleston Community Research to Action Board (CCRAB) in North Charleston as part of the Charleston Area Pollution Prevention Partnership (CAPs) to map local environmental hazards, assess social contamination, perform air quality monitoring, develop mapping tools, and mitigate impacts related to goods movement activities. I have previously performed community-engaged research in NC including Duplin County on industrial hog farming. One of the main organizations that work on EJ issues associated with industrial hog farming in NC is REACH. I have previously worked with REACH on an EPA-funded collaborative problem-solving model project.

B. Positions and Honors

Positions and Employment

2017 – Present Associate Professor, Maryland Institute for Applied Environmental Health, School of Public Health, University of Maryland, College Park, MD

2011 – 2017 Assistant Professor, Maryland Institute for Applied Environmental Health, School of Public Health, University of Maryland, College Park, MD

2007 – 2010 Research Assistant Professor, Institute for Families and Society, College of Social Work, University of South Carolina, Columbia, SC

Other Experience and Professional Memberships

2019 – Present Board Member, Citizen Science Association

2015 – Present Member, National Environmental Justice Advisory Council (NEJAC)

2014 – Present Editorial Board, *Environmental Justice*

2016 – 2019 Member, SESYNC Advisory Board
2010 – 2014 Board of Scientific Counselors, CDC NCEH/ATSDR
2010 – 2012 Member, NAS, Exposure Science in 21st Century Committee
2010 – 2018 Board Member, Community Campus Partnerships for Health (CCPH)
2001 – 2011 Chair, Environment Section, American Public Health Association (APHA)

Research Fellowships, Prizes and Awards

2016 UMD Council on the Environment Junior Faculty of the Year Award
2015 APHA Environment Section Damu Smith Environmental Justice Award
2011 American Public Health Association Leadership Award
2009 EPA Environmental Justice Achievement Award given to LAMC Communities, North Charleston, SC and Mitigation Agreement Committee
2008 EPA Environmental Justice Award given to the West End Revitalization Association, Mebane, NC, member of WERA's project management team
2008 North Carolina Environmental Justice Network Steve Wing International Environmental Justice Award

C. Select Publications

Bodenreider C, Wright L, Barr O, Xu K, **Wilson SM**. Assessment of social, economic, and geographic vulnerability pre-and post-hurricane Harvey in Houston, TX. *Environmental Justice*, *12*(4), 182-193 (2019).

Burwell-Naney K, **Wilson SM**, He X, Sapkota A, Puett R. Development of a Cumulative Stressors and Resiliency Index to Examine Environmental Health Risk: A South Carolina Assessment. *Environmental Justice*, *11*(4), 165-175 (2018).

Chanse V, Mohamed A, **Wilson SM**, Dalemarre L, Leisnham PT, Rockler A, ... Montas H. New Approaches to Facilitate Learning From Youth: Exploring the Use of Photovoice in Identifying Local Watershed Issues. *The J. of Environ. Education*, *48*(2), 109-120 (2017).

Commodore A, **Wilson SM,** Muhammad O, Svendsen E, Pearce JL. Community-based participatory research for the study of air pollution: a review of motivations, approaches, and outcomes. *Environ Monit Assess*. Aug;189(8):378 (2017). PubMed PMID: 28685368.

Wilson SM, Campbell D, Dalemarre L, Fraser-Rahim H, Williams E. A Critical Review of an Authentic and Transformative Community-University Partnership. *IJERPH*. 11(12): 12817-12834 (2014). PMCID: PMC4276648.

Wilson SM, Jiang C, Dalemarre L, Burwell K, Murray R. Environmental Justice Radar: A Tool for Community-Based Mapping to Increase Environmental Awareness and Capacity to Address Environmental Health Issues. *Progress in Community Health Partnerships*. 9(3):439-446 (2015). PMID: 26548796.

Wilson SM, Fraser-Rahim H, Williams E, Zhang H, Svendsen E, Zhang H, Abara W. Assessment of the Distribution of Toxic Release Inventory Facilities in Metropolitan Charleston. *American Journal of Public Health* 102 (10): 1974-80 (2012). PMCID: PMC3490646.

Wilson SM, Aber A, Ravichandran V, et al. Soil Contamination in Urban Communities Impacted by Industrial Pollution and Goods Movement Activities. *Environmental Justice*, *10*(1), 16-22 (2017).

Annang L, **Wilson SM**, Tinago C, Wright Sanders L, Bevington T, Carlos B,… Svendsen E. Photovoice: Assessing the long-term impact of a disaster on a community's quality of life. *Qualitative health research*, *26*(2), 241-251 (2016).

Wilson SM, Richard R, Joseph L, Williams E. Climate Change, Environmental Justice, and Vulnerability: An Exploratory Spatial Analysis. *Environmental Justice*, *3*(1), 13-19 (2010).

BIOGRAPHICAL SKETCH

NAME: Hendricks, Marccus Dwayne

POSITION TITLE: Assistant Professor

EDUCATION/TRAINING:

INSTITUTION AND LOCATION	DEGREE	Completion Date	FIELD OF STUDY
University of North Texas, Denton, TX	BA	12/2010	Psy./Health Promotion
Texas A&M University, College Station, TX	MPH	05/2013	Social and Behavioral Public Health
Texas A&M University, College Station, TX	PhD	05/2017	Urban and Regional Science

A. Personal Statement

I will act as a Co-Investigator on the project entitled: "Building community resilience to natural-disaster-driven contaminant exposures through system-level risk analysis, management, and readiness". I am an Assistant Professor of Urban Studies and Planning in the School of Architecture, Planning, and Preservation and a Faculty Affiliate with the Maryland Institute for Applied Environmental Health in the School of Public Health at the University of Maryland in College Park, Maryland. My other affiliations include the Clark School of Engineering's Center for Disaster Resilience, the National Center for Smart Growth Research and Education, and the Environmental Finance Center. My primary research interests include infrastructure planning and management, social vulnerability to disaster, environmental justice, risk analysis, sustainable development, public health and the built environment, and participatory action research. I use a mixed-methods approach to my research that includes both quantitative and qualitative methods such as multiple regression, cross-sectional research, spatial mapping, in-depth interviewing, participatory action research, and different forms of spatial and analytic epidemiology. At the intersection of my work, I use a combined social vulnerability to disaster and environmental justice framework, to ensure that low-income and communities of color are planned and accounted for, emphasizing participation and action, in light of everyday urban stormwater management and extreme events such as urban flooding and investigates the socio-spatial dynamics related to the inventory, condition, and distribution of critical infrastructures and public works, mainly water infrastructure (i.e. stormwater, wastewater, and drinking water) and green space, can modify risks of hazard exposure, resulting disaster impacts, public health outcomes, and opportunities for community resilience.

To date, I primarily have worked to understand how social processes and development patterns create hazardous human-built environments and particular risks related to urban stormwater management and flooding using secondary thematic spatial data analysis. I have developed and implemented participatory actions, methods, and techniques that create and advance sustainable design, planning, and development decision making of communities to mitigate risks, achieve healthier, more equitable places and resilient natural, built, and social environments.

B. Positions and Honors

Academic Appointments

2017—present Assistant Professor, Urban Studies and Planning Program, School of Architecture, Planning and Preservation, University of Maryland, College Park, MD

Fellowships

2018—2021	Early-Career Research Fellow, JPB Environmental Health Fellowship, T.H. Chan School of Public Health, Harvard University, Cambridge, MA. $240,000 (3-year term)
2018—2020	Early-Career Research Fellow, Gulf Research Program, National Academy of Sciences, Washington, DC. $76,000 (2-year term)

C. Select Publications (*Indicates Students)

Hendricks, Marccus D., Newman, Galen, Yu, Siyu*, & Horney, Jennifer. "Leveling the Landscape: Landscape Performance as a Green Infrastructure Evaluation Tool for Service-Learning Products" *Landscape Journal.*

Masterson, Jaimie, Meyer, Michelle, Gharaibeh, Nasir, **Hendricks, Marccus D.**, …. Van Zandt, Shannon. (2019). "Interdisciplinary Citizen Science for Hazard and Disaster Education." *International Journal of Mass Emergencies and Disasters*, 37(1), 6.

Oti, Isaac*, Gharaibeh, Nasir, **Hendricks, Marccus D.,** Meyer, Michelle, Van Zandt, Shannon, Masterson, Jaimie, Horney, Jennifer, & Berke, Philip. (2019). "Validity and Reliability of Drainage Infrastructure Monitoring Data Obtained from Citizen Scientists." *Journal of Infrastructure Systems*. DOI: 10.1061/(ASCE)IS.1943-555X.0000495

Oti, Isaac*, Gharaibeh, Nasir, Meyer, Michelle, **Hendricks, Marccus D.,** & Van Zandt, Shannon. (2018). "Potential of Citizen Science for Enhancing Infrastructure Monitoring Data and Decision-Support Models for Local Communities." *Risk Analysis.* https://doi.org/10.1111/risa.13256

Meyer, Michelle, **Hendricks, Marccus,** Horney, Jennifer, Berke, Philip R., Masterson, Jaimie, Newman, Galen, Sansom, Garett, Van Zandt, Shannon & Cooper, John. (2018) "Participatory Action Research: Tools for Disaster Resiliency Education." *International Journal of Disaster Resilience in the Built Environment*. DOI: 10.1108/IJDRBE-02-2017-0015

Gibson, Jamesha*, **Hendricks, Marccus D.,** & Wells, Jeremy. (2018) "From Engagement to Empowerment: How Heritage Professionals Can Incorporate Participatory Methods in Disaster Recovery to Better Serve Socially Vulnerable Groups." *International Journal of Heritage Studies,* 1-15, DOI: 10.1080/13527258.2018.1530291

Meyer, Michelle Annette & **Hendricks, Marccus D.** (2018). "Using Photography to Assess Housing Damage and Rebuilding Progress for Disaster Recovery Planning." *Journal of the American Planning Association*, 84:2, 127-144, DOI: 10.1080/01944363.2018.1430606

Hendricks, Marccus D., Meyer, Michelle, Gharaibeh, Nasir, Van Zandt, Shannon, Masterson, Jaimie, Cooper, John, Horney, Jennifer, & Berke, Philip. (2018). "The Development of a Participatory Assessment Technique for Infrastructure: Neighborhood-level Monitoring Towards Sustainable Infrastructure Systems." *Sustainable Cities and Society*, 38, 265-274, DOI: 10.1016/j.scs.2017.12.039

BIOGRAPHICAL SKETCH

NAME: Calder, Ryan Spencer Dyas

POSITION TITLE: Postdoctoral Associate

EDUCATION/TRAINING:

INSTITUTION AND LOCATION	DEGREE	Completion Date	FIELD OF STUDY
Concordia University, Montreal, Canada	BEng	05/2010	Civil Eng. (Environmental Eng.)
Concordia University, Montreal, Canada	MASc	05/2012	Civil Eng. (Hydraulic Eng.)
Harvard University, Cambridge, MA	ScD	05/2017	Env. Health (Risk and Decision Sci.)

A. Personal Statement

My research develops modeling tools to guide environmental and civil infrastructure decision-making in terms of human health and economic impacts. I am interested in developing modeling capacity around large-scale environmental transformations, for which there often exists little empirical data, and which alter the interactions between the environment and nearby populations. I have 10 years' experience developing numerical water quality models and 5 years' experience in epidemiological and toxicokinetic modeling. I leverage training in engineering and public health to build integrated models of environmental systems that can resolve interdisciplinary perspectives in terms of common endpoints. For example, my doctoral work developed modeling capacity for impacts on Indigenous populations of hydroelectric development both in terms of increased methylmercury exposures (neurological and presumed cardiovascular endpoints) and the impacts of fish consumption advisories, which have been the default policy response (neurological, cardiovascular and cancer endpoints).

My work has involved substantial co-production with stakeholders (scientific, government and public, Indigenous and non-Indigenous) and has used and developed blended methodologies for parameterization of quantitative models using scientific data and traditional knowledge. Similarly, my research output has been linked to substantial broader impacts, notably translation of research products into technical reports and analyses solicited by advisory committees and governments (see **Select Publications and Reports**).

In collaboration with the PIs, I will oversee and assist with the development of quantitative environmental, epidemiological and toxicological models. I will support community engagement and co-production efforts as required.

B. Positions and Honors

Positions and Employment

2017—present	Postdoctoral Associate, Department of Civil and Environmental Engineering, Duke University, Durham NC
2008—2012	Successively: Technician, Junior Engineer and Engineer, GHD, Montreal, Canada
2007	Analyst, Quebec Ministry of Sustainable Development, Environment and Parks, Sherbrooke, Canada

Select Awards

2014–2016	Canada Graduate Scholarship (CGS-D), Natural Sciences and Engineering Research Council of Canada (declined and accepted PGS-D for tenure outside Canada)
2014	Postgraduate Scholarship (B1), Fonds de recherche du Québec – nature et technologies (ranked first in earth, atmosphere and water sciences; declined to accept PGS-D award)

C. Select Publications and Reports

Calder, RSD, C Shi, SA Mason, LP Olander and ME Borsuk (2019). 'Forecasting ecosystem services to guide coastal wetland rehabilitation decisions' in *Ecosystem Services*, vol. 39: 1010072.

Kagan, J, ME Borsuk, **RSD Calder**, M Creutzburg, SA Mason, LP Olander, A Plantinga and CS Robinson (2019). 'Assessing Ecosystem Service Benefits from Military Installations', technical report to the Strategic Environmental Research and Development Program, U.S. Department of Defense.

Calder, RSD, S Bromage and EM Sunderland (2018). 'Risk tradeoffs associated with traditional food advisories for Labrador Inuit' in *Environmental Research*, vol. 168: 496–506.

Calder, RSD (2018). 'Effect of soil removal and capping on post-flooding MeHg concentrations in the lower Churchill River environment', technical report for the Independent Expert Advisory Committee, Happy Valley-Goose Bay, NL.

Calder, RSD, AT Schartup, M Li, AP Valberg, PH Balcom and EM Sunderland (2016). 'Future impacts of hydroelectric power development on methylmercury exposures of Canadian indigenous communities' in *Environmental Science & Technology*, vol. 50(23): 1311–13122.

Schartup, AT, PH Balcom, AL Soerensen, KJ Gosnell, **RSD Calder**, RP Mason and EM Sunderland (2015). 'Freshwater discharges drive high levels of methylmercury in Arctic marine biota in *Proceedings of the National Academies of Sciences of the United States of America*, vol. 112(38):11789-94.

Schartup, AT, RSD Calder, M Li, PH Balcom, AP Valberg, J Ewald and EM Sunderland (2015). 'Methylmercury' in Lake Melville: Avativut, Kanuittailinnivut, Nain, NL: Nunatsiavut Government.

Calder, RSD, L Yerushalmi, SS Li (2012). 'Computational fluid dynamics model of BioCAST multienvironment air-lift bioreactor' in *Journal of Environmental Engineering*, vol. 139(6):849-863.

United States
ENVIRONMENTAL PROTECTION AGENCY
Washington, DC 20460

OMB Approval No. 2030-0020
Approval Expires 06/30/17

Current and Pending Support

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Borsuk, Mark E.	Other agencies (including NSF) to which this proposal has been/will be submitted. None.

Support: ☑ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Assessing the Contribution of Small Streams to Use and Non-Use Water Quality Values

Source of Support: Dartmouth College (Prime Sponsor: EPA)
Total Award Amount: 160,743.00 Total Award Period Covered: 04/01/2016 to 03/31/2020
Location of Project: Duke University and Dartmouth College
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 0.00

Support: ☑ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Sources and Protracted Effects of Early Life Exposure to Arsenic and Mercury

Source of Support: Dartmouth College (Prime Sponsor: NIEHS)
Total Award Amount: 33,814.00 Total Award Period Covered: 08/01/2018 to 03/31/2021
Location of Project: Duke University and Dartmouth College
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 0.00

Support: ☑ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Decisions, Risks, and Governance of Geoengineering

Source of Support: Duke University
Total Award Amount: 84,115.00 Total Award Period Covered: 04/01/2018 to 09/30/2020
Location of Project: Duke University, Durham, NC
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 0.00

Support: ☐ Current ☑ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Collaborative Research: Implications of Solar Radiation Management for Strategic Behavior and Climate Governance

Source of Support: National Science Foundation
Total Award Amount: 565,872.00 Total Award Period Covered: 04/01/2020 to 03/31/2023
Location of Project: Duke University, Durham, NC
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 1.00

Support: ☐ Current ☑ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Building community resilience to natural-disaster-driven contaminant exposures through system-level risk analysis, management, and readiness -- THIS PROPOSAL

Source of Support: Environmental Protection Agency
Total Award Amount: 799,756.00 Total Award Period Covered: 05/01/2020 to 04/30/2023
Location of Project: Duke University, Durham, NC
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 0.60

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

United States
ENVIRONMENTAL PROTECTION AGENCY
Washington, DC 20460

OMB Approval No. 2030-0020
Approval Expires 06/30/17

Current and Pending Support

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Calder, Ryan S.

Other agencies (including NSF) to which this proposal has been/will be submitted.
None.

Support: ☐ Current ☑ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Building community resilience to natural-disaster-driven contaminant exposures through system-level risk analysis, management, and readiness -- THIS PROPOSAL

Source of Support: Environmental Protection Agency
Total Award Amount:799,756.00 Total Award Period Covered: 05/01/2020 to 04/30/2023
Location of Project: Duke University, Durham, NC
Person-Months Per Year Committed to the Project. Cal: 2.00 Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal:

Source of Support:
Total Award Amount: Total Award Period Covered: to
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal:

Source of Support:
Total Award Amount: Total Award Period Covered: to
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal:

Source of Support:
Total Award Amount: Total Award Period Covered: to
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal:

Source of Support:
Total Award Amount: Total Award Period Covered: to
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

NCER FORM 5 (9/01) For Use with
EPA STAR Grant Applications

USE ADDITIONAL SHEETS AS NECESSARY

United States
ENVIRONMENTAL PROTECTION AGENCY
Washington, DC 20460

OMB Approval No. 2030-0020
Approval Expires 06/30/17

Current and Pending Support

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Hendricks, Marccus D.	Other agencies (including NSF) to which this proposal has been/will be submitted. None.

Support: ☑ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: The Social Dimensions of Environmental Hazard and Critical Infrastructure Resilience

Source of Support: National Academies of Sciences Gulf Research Program
Total Award Amount: 76,000.00 Total Award Period Covered: 09/01/2018 to 08/31/2020
Location of Project: DC, Maryland, Houston
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 0.50

Support: ☑ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: A Multimethod Approach to Assess Sanitary Risks and Microbial Exposures Associated with Vulnerable Infrastructure and Public Works in Baltimore, Maryland

Source of Support: JPB Foundation and Harvard T. H. Chan School of Public Health
Total Award Amount: 41,752.00 Total Award Period Covered: 09/01/2019 to 08/31/2020
Location of Project: Baltimore, MD
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 1.00

Support: ☑ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: A Smart, Connected, and Sustainable Campus Community: Using the Internet of Things (IoT) and Sensor Technology to Improve Stormwater Management at UMD

Source of Support: UMD Sustainability Fund
Total Award Amount: 42,710.00 Total Award Period Covered: 05/01/2019 to 08/01/2020
Location of Project: College Park, MD
Person-Months Per Year Committed to the Project. Cal: Acad: 1.00 Sumr:

Support: ☐ Current ☑ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Building community resilience to natural-disaster-driven contaminant exposures through system-level risk analysis, management, and readiness -- THIS PROPOSAL

Source of Support: Duke University (EPA Flow Through)
Total Award Amount: 799,756.00 Total Award Period Covered: 05/01/2020 to 04/30/2023
Location of Project: University of Maryland, College Park
Person-Months Per Year Committed to the Project. Cal: Acad: 0.18 Sumr: 1.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal:

Source of Support:
Total Award Amount: Total Award Period Covered: to
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

United States
ENVIRONMENTAL PROTECTION AGENCY
Washington, DC 20460

OMB Control No. 2030-0020
Approval expires 04/30/2021

Current and Pending Support

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Wilson, Sacoby	Other agencies (including NSF) to which this proposal has been/will be submitted. None.

Support: ☑ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: CNH-L: Stormwater Management Across Urban Ecosystems: Diagnostic Tools and Community Engagement for Ecological Restoration, Equitable Community Development and Revitalization

Source of Support: NSF
Total Award Amount: 1,499,833.00 Total Award Period Covered: 09/15/2018 to 02/28/2023
Location of Project: University of Maryland, College Park
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.00 Sumr: 0.65

Support: ☑ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Park Equity and Environmental Health Benefits Tool

Source of Support: Maryland Department of Natural Resources
Total Award Amount: 75,000.00 Total Award Period Covered: 12/01/2018 to 09/30/2019
Location of Project: University of Maryland, College Park
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.90 Sumr: 0.00

Support: ☐ Current ☑ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Building community resilience to natural-disaster-driven contaminant exposures through system-level risk analysis, management, and readiness -- THIS PROPOSAL

Source of Support: Duke University (EPA Flow Through)
Total Award Amount:799,756.00 Total Award Period Covered: 05/01/2020 to 04/30/2023
Location of Project: University of Maryland, College Park
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.18 Sumr: 1.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal:

Source of Support:
Total Award Amount: Total Award Period Covered: to
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal:

Source of Support:
Total Award Amount: Total Award Period Covered: to
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

KEY CONTACTS FORM

Authorized Representative: *Original awards and amendments will be sent to this individual for review and acceptance, unless otherwise indicated.*

Name: Evan Crierie
Title: Assistant Director
Complete Address: 7809 Regents Drive, 3112 Lee Building, College Park, MD 20742-5141
Office or Research Administration; Email: oraa@umd.edu
Phone Number: 301-405-6269

Payee: *Individual authorized to accept payments.*

Name: University of Maryland
Title: Sponsored Program Accounting & Compliance
Mail Address: 4300 Terrapin Trail, 4101 Chesapeake Building, College Park, MD 20742-3141

Phone Number: 301-405-2607

Administrative Contact: *Individual from Sponsored Program Office to contact concerning administrative matters (i.e., indirect cost rate computation, rebudgeting requests etc.)*

Name: Joeleen Grant-Paterniti
Title: Contract Administrator
Mailing Address: 7809 Regents Drive, 3112 Lee Building, College Park, MD 20742-5141

Phone Number: 301-405-6269
FAX Number: 301-314-9569
E-Mail Address: oraa@umd.edu

Principal Investigator: *Individual responsible for the technical completion of the proposed work.*

Name: Sacoby Wilson
Title: Associate Professor
Mailing Address: 4200 Valley Drive, 2234D School of Public Health Bldg., College Park, MD 20742-0001

Phone Number: 301-405-3136
FAX Number:
E-Mail Address: swilson2@umd.edu
Web URL: sph.umd.edu

OMB Number: 2030-0020
Expiration Date: 04/30/2021

Preaward Compliance Review Report for All Applicants and Recipients Requesting EPA Financial Assistance

Note: Read Instructions before completing form.

I. A. Applicant/Recipient (Name, Address, City, State, Zip Code)

Name: Duke University

Address: 2200 W. Main St. Ste 710

City: Durham

State: NC: North Carolina Zip Code: 27705-4677

B. DUNS No. 044387793

II. Is the applicant currently receiving EPA Assistance? ☒ Yes ☐ No

III. List all civil rights lawsuits and administrative complaints pending against the applicant/recipient that allege discrimination based on race, color, national origin, sex, age, or disability. (Do not include employment complaints not covered by 40 C.F.R. Parts 5 and 7.)

See Attachment A

IV. List all civil rights lawsuits and administrative complaints decided against the applicant/recipient within the last year that allege discrimination based on race, color, national origin, sex, age, or disability and enclose a copy of all decisions. Please describe all corrective actions taken. (Do not include employment complaints not covered by 40 C.F.R. Parts 5 and 7.)

See Attachments A and B

V. List all civil rights compliance reviews of the applicant/recipient conducted by any agency within the last two years and enclose a copy of the review and any decisions, orders, or agreements based on the review. Please describe any corrective action taken. (40 C.F.R. § 7.80(c)(3))

See Attachments A and C

VI. Is the applicant requesting EPA assistance for new construction? If no, proceed to VII; if yes, answer (a) and/or (b) below.

☐ Yes ☒ No

a. If the grant is for new construction, will all new facilities or alterations to existing facilities be designed and constructed to be readily accessible to and usable by persons with disabilities? If yes, proceed to VII; if no, proceed to VI(b).

☐ Yes ☐ No

b. If the grant is for new construction and the new facilities or alterations to existing facilities will not be readily accessible to and usable by persons with disabilities, explain how a regulatory exception (40 C.F.R. 7.70) applies.

VII. Does the applicant/recipient provide initial and continuing notice that it does not discriminate on the basis of race, color, national origin, sex, age, or disability in its program or activities? (40 C.F.R 5.140 and 7.95) ☒ Yes ☐ No

a. Do the methods of notice accommodate those with impaired vision or hearing? ☒ Yes ☐ No

b. Is the notice posted in a prominent place in the applicant's offices or facilities or, for education programs and activities, in appropriate periodicals and other written communications? ☒ Yes ☐ No

c. Does the notice identify a designated civil rights coordinator? ☒ Yes ☐ No

VIII. Does the applicant/recipient maintain demographic data on the race, color, national origin, sex, age, or handicap of the population it serves? (40 C.F.R. 7.85(a)) ☒ Yes ☐ No

IX. Does the applicant/recipient have a policy/procedure for providing access to services for persons with limited English proficiency? (40 C.F.R. Part 7, E.O. 13166) ☒ Yes ☐ No

X. If the applicant is an education program or activity, or has 15 or more employees, has it designated an employee to coordinate its compliance with 40 C.F.R. Parts 5 and 7? Provide the name, title, position, mailing address, e-mail address, fax number, and telephone number of the designated coordinator.

Kimberly Hewitt, Vice President for Institutional Equity & Chief Diversity Officer
114 S. Buchanan Blvd. Bay 8, Box 90012, Durham, NC 27708
919-684-8228, kimberly.hewitt@duke.edu

XI. If the applicant is an education program or activity, or has 15 or more employees, has it adopted grievance procedures that assure the prompt and fair resolution of complaints that allege a violation of 40 C.F.R. Parts 5 and 7? Provide a legal citation or Internet Address for, or a copy of, the procedures.

https://oie.duke.edu/

For the Applicant/Recipient

I certify that the statements I have made on this form and all attachments thereto are true, accurate and complete. I acknowledge that any knowingly false or misleading statement may be punishable by fine or imprisonment or both under applicable law. I assure that I will fully comply with all applicable civil rights statutes and EPA regulations.

A. Signature of Authorized Official	B. Title of Authorized Official	C. Date
Susan Lasley	Assistant Director, ORS	09/30/2019

For the U.S. Environmental Protection Agency

I have reviewed the information provided by the applicant/recipient and hereby certify that the applicant/recipient has submitted all preaward compliance information required by 40 C.F.R. Parts 5 and 7; that based on the information submitted, this application satisfies the preaward provisions of 40 C.F.R. Parts 5 and 7; and that the applicant has given assurance that it will fully comply with all applicable civil rights statures and EPA regulations.

A. *Signature of Authorized EPA Official	B. Title of Authorized Official	C. Date

*** See Instructions**

Instructions for EPA FORM 4700-4 (Rev. 06/2014)

General. Recipients of Federal financial assistance from the U.S. Environmental Protection Agency must comply with the following statutes and regulations.
Title VI of the Civil Rights Acts of 1964 provides that no person in the United States shall, on the grounds of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance. The Act goes on to explain that the statute shall not be construed to authorize action with respect to any employment practice of any employer, employment agency, or labor organization (except where the primary objective of the Federal financial assistance is to provide employment). Section 13 of the 1972 Amendments to the Federal Water Pollution Control Act provides that no person in the United States shall on the ground of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under the Federal Water Pollution Control Act, as amended. Employment discrimination on the basis of sex is prohibited in all such programs or activities. Section 504 of the Rehabilitation Act of 1973 provides that no otherwise qualified individual with a disability in the United States shall solely by reason of disability be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance. Employment discrimination on the basis of disability is prohibited in all such programs or activities. The Age Discrimination Act of 1975 provides that no person on the basis of age shall be excluded from participation under any program or activity receiving Federal financial assistance. Employment discrimination is not covered. Age discrimination in employment is proh bited by the Age Discrimination in Employment Act administered by the Equal Employment Opportunity Commission. Title IX of the Education Amendments of 1972 provides that no person in the United States on the basis of sex shall be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving Federal financial assistance. Employment discrimination on the basis of sex is prohibited in all such education programs or activities. Note: an education program or activity is not limited to only those conducted by a formal institution. 40 C.F.R. Part 5 implements Title IX of the Education Amendments of 1972. 40 C.F.R. Part 7 implements Title VI of the Civil Rights Act of 1964, Section 13 of the 1972 Amendments to the Federal Water Pollution Control Act, and Section 504 of The Rehabilitation Act of 1973. The Executive Order 13166 (E.O. 13166) entitled; "Improving Access to Services for Persons with Limited English Proficiency" requires Federal agencies work to ensure that recipients of Federal financial assistance provide meaningful access to their LEP applicants and beneficiaries.

Items “Applicant” means any entity that files an application or unsolicited proposal or otherwise requests EPA assistance. 40 C.F.R. §§ 5.105, 7.25. “Recipient” means any entity, other than applicant, which will actually receive EPA assistance. 40 C.F.R. §§ 5.105, 7.25. “Civil rights lawsuits and administrative complaints” means any lawsuit or administrative complaint alleging discrimination on the basis of race, color, national origin, sex, age, or disability pending or decided against the applicant and/or entity which actually benefits from the grant, but excluding employment complaints not covered by 40 C.F.R. Parts 5 and 7. For example, if a city is the named applicant but the grant will actually benefit the Department of Sewage, civil rights lawsuits involving both the city and the Department of Sewage should be listed. “Civil rights compliance review” means any review assessing the applicant’s and/or recipient’s compliance with laws proh biting discrimination on the basis of race, color, national origin, sex, age, or disability. Submit this form with the original and required copies of applications, requests for extensions, requests for increase of funds, etc. Updates of information are all that are required after the initial application submission. If any item is not relevant to the project for which assistance is requested, write “NA” for “Not Applicable.” In the event applicant is uncertain about how to answer any questions, EPA program officials should be contacted for clarification. * Note: Signature appears in the Approval Section of the EPA Comprehensive Administrative Review For Grants/Cooperative Agreements & Continuation/Supplemental Awards form.

OMB Number: 4040-0007
Expiration Date: 02/28/2022

ASSURANCES - NON-CONSTRUCTION PROGRAMS

PLEASE DO NOT RETURN YOUR COMPLETED FORM TO THE OFFICE OF MANAGEMENT AND BUDGET. SEND IT TO THE ADDRESS PROVIDED BY THE SPONSORING AGENCY.

NOTE: Certain of these assurances may not be applicable to your project or program. If you have questions, please contact the awarding agency. Further, certain Federal awarding agencies may require applicants to certify to additional assurances. If such is the case, you will be notified.

As the duly authorized representative of the applicant, I certify that the applicant:

1. Has the legal authority to apply for Federal assistance and the institutional, managerial and financial capability (including funds sufficient to pay the non-Federal share of project cost) to ensure proper planning, management and completion of the project described in this application.

2. Will give the awarding agency, the Comptroller General of the United States and, if appropriate, the State, through any authorized representative, access to and the right to examine all records, books, papers, or documents related to the award; and will establish a proper accounting system in accordance with generally accepted accounting standards or agency directives.

3. Will establish safeguards to prohibit employees from using their positions for a purpose that constitutes or presents the appearance of personal or organizational conflict of interest, or personal gain.

4. Will initiate and complete the work within the applicable time frame after receipt of approval of the awarding agency.

5. Will comply with the Intergovernmental Personnel Act of 1970 (42 U.S.C. §§4728-4763) relating to prescribed standards for merit systems for programs funded under one of the 19 statutes or regulations specified in Appendix A of OPM's Standards for a Merit System of Personnel Administration (5 C.F.R. 900, Subpart F).

6. Will comply with all Federal statutes relating to nondiscrimination. These include but are not limited to: (a) Title VI of the Civil Rights Act of 1964 (P.L. 88-352) which prohibits discrimination on the basis of race, color or national origin; (b) Title IX of the Education Amendments of 1972, as amended (20 U.S.C.§§1681-1683, and 1685-1686), which prohibits discrimination on the basis of sex; (c) Section 504 of the Rehabilitation Act of 1973, as amended (29 U.S.C. §794), which prohibits discrimination on the basis of handicaps; (d) the Age Discrimination Act of 1975, as amended (42 U.S.C. §§6101-6107), which prohibits discrimination on the basis of age; (e) the Drug Abuse Office and Treatment Act of 1972 (P.L. 92-255), as amended, relating to nondiscrimination on the basis of drug abuse; (f) the Comprehensive Alcohol Abuse and Alcoholism Prevention, Treatment and Rehabilitation Act of 1970 (P.L. 91-616), as amended, relating to nondiscrimination on the basis of alcohol abuse or alcoholism; (g) §§523 and 527 of the Public Health Service Act of 1912 (42 U.S.C. §§290 dd-3 and 290 ee- 3), as amended, relating to confidentiality of alcohol and drug abuse patient records; (h) Title VIII of the Civil Rights Act of 1968 (42 U.S.C. §§3601 et seq.), as amended, relating to nondiscrimination in the sale, rental or financing of housing; (i) any other nondiscrimination provisions in the specific statute(s) under which application for Federal assistance is being made; and, (j) the requirements of any other nondiscrimination statute(s) which may apply to the application.

7. Will comply, or has already complied, with the requirements of Titles II and III of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (P.L. 91-646) which provide for fair and equitable treatment of persons displaced or whose property is acquired as a result of Federal or federally-assisted programs. These requirements apply to all interests in real property acquired for project purposes regardless of Federal participation in purchases.

8. Will comply, as applicable, with provisions of the Hatch Act (5 U.S.C. §§1501-1508 and 7324-7328) which limit the political activities of employees whose principal employment activities are funded in whole or in part with Federal funds.

9. Will comply, as applicable, with the provisions of the Davis-Bacon Act (40 U.S.C. §§276a to 276a-7), the Copeland Act (40 U.S.C. §276c and 18 U.S.C. §874), and the Contract Work Hours and Safety Standards Act (40 U.S.C. §§327-333), regarding labor standards for federally-assisted construction subagreements.

10. Will comply, if applicable, with flood insurance purchase requirements of Section 102(a) of the Flood Disaster Protection Act of 1973 (P.L. 93-234) which requires recipients in a special flood hazard area to participate in the program and to purchase flood insurance if the total cost of insurable construction and acquisition is $10,000 or more.

11. Will comply with environmental standards which may be prescribed pursuant to the following: (a) institution of environmental quality control measures under the National Environmental Policy Act of 1969 (P.L. 91-190) and Executive Order (EO) 11514; (b) notification of violating facilities pursuant to EO 11738; (c) protection of wetlands pursuant to EO 11990; (d) evaluation of flood hazards in floodplains in accordance with EO 11988; (e) assurance of project consistency with the approved State management program developed under the Coastal Zone Management Act of 1972 (16 U.S.C. §§1451 et seq.); (f) conformity of Federal actions to State (Clean Air) Implementation Plans under Section 176(c) of the Clean Air Act of 1955, as amended (42 U.S.C. §§7401 et seq.); (g) protection of underground sources of drinking water under the Safe Drinking Water Act of 1974, as amended (P.L. 93-523); and, (h) protection of endangered species under the Endangered Species Act of 1973, as amended (P.L. 93-205).

12. Will comply with the Wild and Scenic Rivers Act of 1968 (16 U.S.C. §§1271 et seq.) related to protecting components or potential components of the national wild and scenic rivers system.

13. Will assist the awarding agency in assuring compliance with Section 106 of the National Historic Preservation Act of 1966, as amended (16 U.S.C. §470), EO 11593(identification and protection of historic properties), and the Archaeological and Historic Preservation Act of 1974 (16 U.S.C. §§469a-1 et seq.).

14. Will comply with P.L. 93-348 regarding the protection of human subjects involved in research, development, and related activities supported by this award of assistance.

15. Will comply with the Laboratory Animal Welfare Act of 1966 (P.L. 89-544, as amended, 7 U.S.C. §§2131 et seq.) pertaining to the care, handling, and treatment of warm blooded animals held for research, teaching, or other activities supported by this award of assistance.

16. Will comply with the Lead-Based Paint Poisoning Prevention Act (42 U.S.C. §§4801 et seq.) which prohibits the use of lead-based paint in construction or rehabilitation of residence structures.

17. Will cause to be performed the required financial and compliance audits in accordance with the Single Audit Act Amendments of 1996 and OMB Circular No. A-133, "Audits of States, Local Governments, and Non-Profit Organizations."

18. Will comply with all applicable requirements of all other Federal laws, executive orders, regulations, and policies governing this program.

19. Will comply with the requirements of Section 106(g) of the Trafficking Victims Protection Act (TVPA) of 2000, as amended (22 U.S.C. 7104) which prohibits grant award recipients or a sub-recipient from (1) Engaging in severe forms of trafficking in persons during the period of time that the award is in effect (2) Procuring a commercial sex act during the period of time that the award is in effect or (3) Using forced labor in the performance of the award or subawards under the award.

SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL	TITLE
Susan Lasley	Assistant Director, ORS
APPLICANT ORGANIZATION	DATE SUBMITTED
Duke University	09/30/2019

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Attachment A

Item III.

Date Filed	Agency / Court	Charge / Complaint #	Alleged Discrimination		
9/18/2015	OCR	11/15/2058	Sex	Disability	Age
11/9/2015	OCR	11/15/2325	Sex	Disability	Age
11/20/2015	OCR	11/15/2264	Sex		
8/11/2016	OCR	11/16/2026	Age		
3/9/2018	USDC / MDNC	18-CV-00288	National Origin		
5/29/2018	USDC / MDNC	18-CV-00461	Disability		
3/28/2019	OCR	11/19/6902	Disability		
6/25/2019	OCR	11/19/2214	National Origin		
7/3/2019	USDC / MDNC	19-CV-00664	Sex	Race	Sex
8/7/2019	OCR	11/19/2224	Sex		

Item IV.

Date Filed	Agency / Court	Charge / Complaint #	Alleged Discrimination		
11/4/2016	USDC / MDNC	16-CV-1296 / AAA #17-0003-7726	Race		

Item V.

Date Filed	Agency / Court	Audit #	Comment
8/26/2016	USDOL / OFCCP	R00201328	Completed - 5/31/2019

Attachment B

THE AMERICAN ARBITRATION ASSOCIATION
EMPLOYMENT ARBITRATION TRIBUNAL

TASHA CARMON **Claimant,**	)	
v.	)	**Case No. 01-17-0003-7726**
DUKE UNIVERSITY, **Respondent.**	)	

FINAL AWARD OF ARBITRATOR

I, THE UNDERSIGNED ARBITRATOR, having been designated in accordance with the personnel manual or employment agreement entered into by the above-named parties and having been duly sworn, and having duly heard the proofs and allegations of the Parties, and Claimant, Tasha Carmon being represented by Wilson Fong of Hensel Law, PLLC and Respondent, Duke University being represented by Robert Sar and Kimberly Lehman of Ogletree Deakins, hereby ORDERS, as follows:

On August 27, 2018, the Arbitrator issued the "Interim Award of Arbitrator," which provided certain monetary relief to Claimant Tasha Carmon, and ordered further briefing on two issues: (1) the calculation of prejudgment interest on the back pay award; and (2) "reasonable attorneys' fees and costs upon submission of an itemization and appropriate affidavits." *See* Interim Award (Aug. 27, 2018). On September 24, 2018, the Arbitrator issued the "Supplemental Order" which directed Claimant to provide a redacted version of the time records and costs (with an unredacted version provided *ex parte* for *in camera* review by the Arbitrator), and directed the Claimant to exclude time and costs spent on the district court proceedings.

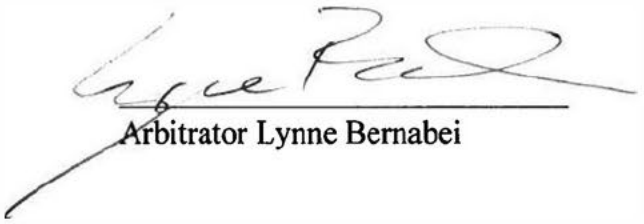
Claimant provided the requested documentation on October 5, 2018, and Respondent submitted its response on October 12, 2018. The fees sought were reduced to $30,734.00, and the costs sought were reduced to $1,556.05, for a total of $32,290.05. Respondent objected that a total of 1.0 hours (three time entries) with a value of $300 were improperly included as they related to the district court case, and that the district court filing fee, $400, was also improperly included, for a total of $700 in objected-to fees and costs. I agree with Respondent's objections.

In light of the foregoing, I make the following Final Award, which supplements the monetary relief set forth in the August 27, 2018 Interim Award:

1) Claimant is entitled to $9,073.99 in prejudgment interest on the back pay award, and $31,590.05 in attorneys' fees and costs, both of which shall be payable by Respondent

within twenty (20) calendar days after Claimant provides Respondent with the information needed for processing the payment.

The administrative fees of the American Arbitration Association, totaling $2,400.00 and the compensation and expenses of the arbitrator, totaling $18,684.44 shall be borne as incurred.



Dated: October 25, 2018

Arbitrator Lynne Bernabei

Attachment C

U.S. Department of Labor

Office of Federal Contract Compliance Programs
Pacific Regional Office
90 Seventh Street, Suite 18-300
San Francisco, CA 94103

Via Certified Mail, Return Receipt Requested
(#7001 0320 0004 6350 4106)

May 31, 2019

VINCENT E. PRICE
President
Duke University
207 Allen Building, BOX 90001
Durham, NC 27708-0001

Re: OFCCP Compliance Evaluation of Duke University, #R00201328

Dear Mr. Price:

The U.S. Department of Labor, Office of Federal Contract Compliance Programs (OFCCP), recently completed a compliance evaluation of your equal employment opportunity policies and practices at 2200 West Main Street, Ste 710, Durham, NC 27705-4677.

During the compliance evaluation process, we identified the following potential violations pursuant to 41 CFR 60-1.12 (e), 41 CFR 60-2.1 through 60-2.17; 41 CFR 60-741.40 through 60-741.47, 41 CRF 60 741.80 (c); and 41 CFR 60-300.40 through 60-300.45, 41 CFR 60-300.80 (c):

a) Applicant tracking- limited applicant flow data and some areas information was unavailable and could not be reconstructed.

b) Recordkeeping - limited applicant flow data and some areas information was unavailable and could not be reconstructed.

c) Self-ID -Not all applicants were given opportunity to self-ID.

d) Internal audit & reporting -Issues were not being monitored (i.e. applicant tracking, recordkeeping, self-ID, failure to disclose adverse impact analysis, etc.).

e) Failure to disclose adverse impact analysis Adverse impact analysis for faculty was not done. Adverse impact analysis that was provided for staff in December 2018 is likely not based on reliable data.

f) Availability analysis -Non-regular rank faculty, temp, part-time, undergraduate, graduate, intern, and non-Duke student employees were not included.

The above potential violations were discussed with the contractor's attorney as part of our transparency directive regarding pending issues in the case. It is understood that these potential violations will not recur.

There were no other apparent violations of Executive Order 11246, Section 503 or Section 4212. This determination may be modified by the Regional Director, or by the Director of OFCCP, within 45 calendar days of the issuance of this letter. The OFCCP appreciates the cooperation of you and your staff during the conduct of the compliance review.

Sincerely,

FOR

Luis Rodriguez
Director of Regional Operations
Pacific Region

Cc: Gretchen Ewalt, Attorney, Ogletree, Deakins, Smak & Stewart, P.C.,
Gretchen.ewalt@ogletree.com

DEPARTMENT OF HEALTH AND HUMAN SERVICES

ASSURANCE OF COMPLIANCE

ASSURANCE OF COMPLIANCE WITH TITLE VI OF THE CIVIL RIGHTS ACT OF 1964, SECTION 504 OF THE REHABILITATION ACT OF 1973, TITLE IX OF THE EDUCATION AMENDMENTS OF 1972, THE AGE DISCRIMINATION ACT OF 1975, AND SECTION 1557 OF THE AFFORDABLE CARE ACT

The Applicant provides this assurance in consideration of and for the purpose of obtaining Federal grants, loans, contracts, property, discounts or other Federal financial assistance from the U.S. Department of Health and Human Services.

THE APPLICANT HEREBY AGREES THAT IT WILL COMPLY WITH:

1. Title VI of the Civil Rights Act of 1964 (Pub. L. 88-352), as amended, and all requirements imposed by or pursuant to the Regulation of the Department of Health and Human Services (45 C.F.R. Part 80), to the end that, in accordance with Title VI of that Act and the Regulation, no person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Applicant receives Federal financial assistance from the Department.

2. Section 504 of the Rehabilitation Act of 1973 (Pub. L. 93-112), as amended, and all requirements imposed by or pursuant to the Regulation of the Department of Health and Human Services (45 C.F.R. Part 84), to the end that, in accordance with Section 504 of that Act and the Regulation, no otherwise qualified individual with a disability in the United States shall, solely by reason of her or his disability, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity for which the Applicant receives Federal financial assistance from the Department.

3. Title IX of the Education Amendments of 1972 (Pub. L. 92-318), as amended, and all requirements imposed by or pursuant to the Regulation of the Department of Health and Human Services (45 C.F.R. Part 86), to the end that, in accordance with Title IX and the Regulation, no person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any education program or activity for which the Applicant receives Federal financial assistance from the Department.

4. The Age Discrimination Act of 1975 (Pub. L. 94-135), as amended, and all requirements imposed by or pursuant to the Regulation of the Department of Health and Human Services (45 C.F.R. Part 91), to the end that, in accordance with the Act and the Regulation, no person in the United States shall, on the basis of age, be denied the benefits of, be excluded from participation in, or be subjected to discrimination under any program or activity for which the Applicant receives Federal financial assistance from the Department.

5. Section 1557 of the Affordable Care Act (Pub. L. 111-148), as amended, and all requirements imposed by or pursuant to the Regulation of the Department of Health and Human Services (45 CFR Part 92), to the end that, in accordance with Section 1557 and the Regulation, no person in the United States shall, on the ground of race, color, national origin, sex, age, or disability be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any health program or activity for which the Applicant receives Federal financial assistance from the Department.

The Applicant agrees that compliance with this assurance constitutes a condition of continued receipt of Federal financial assistance, and that it is binding upon the Applicant, its successors, transferees and assignees for the period during which such assistance is provided. If any real property or structure thereon is provided or improved with the aid of Federal financial assistance extended to the Applicant by the Department, this assurance shall obligate the Applicant, or in the case of any transfer of such property,any transferee, for the period during which the real property or structure is used for a purpose for which the Federal financial assistance is extended or for another purpose involving the provision of similar services or benefits. If any personal property is so provided, this assurance shall obligate the Applicant for the period during which it retains ownership or possession of the property. The Applicant further recognizes and agrees that the United States shall have the right to seek judicial enforcement of this assurance.

The person whose signature appears below is authorized to sign this assurance and commit the Applicant to the above provisions.

July 1, 2019
Date

Signature of Authorized Official

Tallman Trask, III Executive Vice President
Name and Title of Authorized Official (please print or type)

Please mail form to:

U.S. Department of Health & Human Services
Office for Civil Rights
200 Independence Ave., S.W. Room 509F
Washington, D.C. 20201

Duke University
Name of Agency Receiving/Requesting Funding

203 Allen Building
Street Address

Durham, NC 27707
City, State, Zip Code

BUDGET INFORMATION - Non-Construction Programs

OMB Number: 4040-0006
Expiration Date: 02/28/2022

SECTION A - BUDGET SUMMARY

Grant Program Function or Activity (a)	Catalog of Federal Domestic Assistance Number (b)	Estimated Unobligated Funds		New or Revised Budget		
		Federal (c)	Non-Federal (d)	Federal (e)	Non-Federal (f)	Total (g)
1. Science To Achieve Results (STAR) Research Program	66.509	$ 0.00	$ 0.00	$ 799,756.00	$ 0.00	$ 799,756.00
2.						
3.						
4.						
5. Totals		$ 0.00	$ 0.00	$ 799,756.00	$ 0.00	$ 799,756.00

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SECTION B - BUDGET CATEGORIES

6. Object Class Categories	GRANT PROGRAM, FUNCTION OR ACTIVITY (1)	(2)	(3)	(4)	Total (5)
	Science To Achieve Results (STAR) Research Program	N/A	N/A		
a. Personnel	$				
b. Fringe Benefits					
c. Travel					
d. Equipment					
e. Supplies					
f. Contractual					
g. Construction					
h. Other					
i. Total Direct Charges (sum of 6a-6h)					
j. Indirect Charges					
k. TOTALS (sum of 6i and 6j)	$ 271,085.00	$ 258,550.00	$ 270,121.00	$	$ 799,756.00
7. Program Income	$ 0.00	$ 0.00	$ 0.00	$	$ 0.00

(b) (6)

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SECTION C - NON-FEDERAL RESOURCES

(a) Grant Program	(b) Applicant	(c) State	(d) Other Sources	(e)TOTALS
8. Science To Achieve Results (STAR) Research Program	$ 0.00	$ 0.00	$ 0.00	$ 0.00
9.				
10.				
11.				
12. TOTAL (sum of lines 8-11)	$ 0.00	$ 0.00	$ 0.00	$ 0.00

SECTION D - FORECASTED CASH NEEDS

	Total for 1st Year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
13. Federal	$ 271,085.00	$ 67,772.00	$ 67,771.00	$ 67,771.00	$ 67,771.00
14. Non-Federal	$ 0.00	0.00	0.00	0.00	0.00
15. TOTAL (sum of lines 13 and 14)	$ 271,085.00	$ 67,772.00	$ 67,771.00	$ 67,771.00	$ 67,771.00

SECTION E - BUDGET ESTIMATES OF FEDERAL FUNDS NEEDED FOR BALANCE OF THE PROJECT

(a) Grant Program	FUTURE FUNDING PERIODS (YEARS) (b)First	(c) Second	(d) Third	(e) Fourth
16. Science To Achieve Results (STAR) Research Program	$ 271,085.00	$ 258,550.00	$ 270,121.00	$
17.				
18.				
19.				
20. TOTAL (sum of lines 16 - 19)	$ 271,085.00	$ 258,550.00	$ 270,121.00	$

SECTION F - OTHER BUDGET INFORMATION

21. Direct Charges: $639,051

22. Indirect Charges: 61% Fixed MTDC, $263,450 Base amount, $160,705 IDC

23. Remarks: